Hot Water
FOR
Domestic Use

HOT WATER FOR DOMESTIC USE

A Complete Guide to the Methods of Supplying and Heating Water for Domestic Purposes, giving each step to be taken and explaining why it is done.

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HOT WATER FOR DOMESTIC USE

Circulation of Hot Water.

UNDERLYING PRINCIPLES.

To thoroughly understand how water can be heated and distributed throughout a building in pipes, so that upon opening a faucet a plentiful supply of hot water can be obtained at all fixtures, it is first necessary to understand the principles which underlie the heating of water for domestic use; to be familiar with the properties of hot water, and understand the behavior of water when subjected to heat or cold.

It is a well-known property of water, that, at ordinary temperatures, when subjected to heat it will expand; consequently if a certain quantity of water, which at a low temperature would just fill a measure, be heated, part of the liquid will overflow from the measure, and while the measure would still remain full, the weight of the liquid would be less than before heat was applied. Quantity of water must not be confused with unit measure of water. For instance, if a gallon of water be put in a vessel large enough to contain more than a gallon, and the water be heated, the quantity of water at the new temperature will weigh exactly

the same as it did before being heated, *but there will be a greater quantity of water* in the vessel, and if from that greater quantity of water, one gallon be measured out it will weigh less than the gallon of water originally put in the vessel. In other words, heating water increases its bulk but decreases its weight per unit measure, while conversely, cooling of water decreases its bulk but increases its weight per unit measure.

The foregoing statement is the rule, but there is an exception to the rule. When water has a temperature of 39° Fahrenheit it is at its maximum density, and the application of either heat or cold will then cause it to increase its bulk.

CAUSE OF WATER CIRCULATION.

It is due to this difference in weight between two equal volumes of water at different temperatures, that circulation takes place, and makes possible the heating of a large tank or body of water by applying heat at only one point.

LOCAL CIRCULATION OF WATER.

Local circulation of water, or the circulation of water within an open vessel or tank, will be better understood by a reference to Fig. 1. If heat be applied to the center of the tank, as shown in the illustration, the water immediately above where the heat is applied, will become warmer, increase in bulk and decrease correspondingly in weight and will

be displaced by a colder and heavier column of water, flowing down around the sides of the vessel to the bottom. As the heated water from the bottom of the tank rises to the surface it comes in contact with colder water and air to which it imparts some of its heat. The constant rising of water near the center of the vessel forces the water to the sides and in passing down along the walls of the vessel the water parts with more heat until, having arrived at the point where it has the lowest

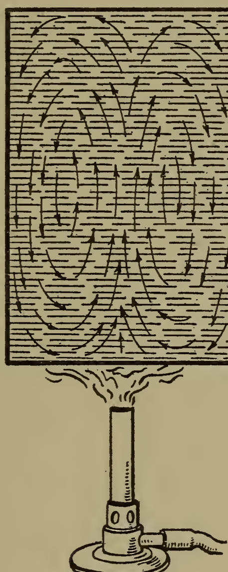

Fig. 1.

temperature of any water in the tank, it again is brought to the center immediately above the flame to displace the heated water, and so in turn again makes the circuit. This constant traveling of water from the bottom of a tank and back again is known as local circulation and it is due to this circulation that we are able to heat water in a vessel. If instead of applying heat to the bottom of the tank it were applied to the surface of the water, no circulation would take place, and outside of the uppermost layers the temperature of the water within the vessel, would not be raised.

HEAT AND TEMPERATURE.

The terms heat and temperature should not be confused. Heat has reference to the quantity of heat required by a body to raise its temperature. Heat is commonly accepted as a form of energy, a vibration or wave motion of the molecules composing matter. According to the generally accepted theory, the molecules that compose matter are in a constant state of unrest which keeps them moving back and forth, or vibrating with a greater or less velocity. It is this movement of the molecules which is generally believed to cause the sensation of warmth and cold; when the motion is slow, the matter feels cold, whereas when the motion is rapid, the body feels warm.

Heat not being a substance cannot be measured by any of the usual weights or measures, but as it

produces certain effects it can be measured by the effects it produces. It is obvious that if two balls of metal of different sizes are heated to the same temperature, that one ball, the larger one, will require more heat than did the smaller one. Again, suppose that it takes a certain amount of heat to raise the temperature of one pound of water one degree Fahrenheit, then it would take just double that amount of heat to raise two pounds of water one degree Fahrenheit, and three times the amount of heat to raise three pounds of water one degree Fahrenheit. Further, if it takes a certain amount of heat to raise one pound of water one degree, it would take twice that quantity of heat to raise the same quantity of water two degrees Fahrenheit, and three times the amount of heat to raise the temperature of the water three degrees Fahrenheit.

Unit of Heat.

It follows from the foregoing explanation that there is some unit by which heat can be measured. This unit is known as a British Thermal unit, which is usually abbreviated to B. T. U. A British Thermal Unit is the quantity of heat required to raise the temperature of a pound of water from 62° to 63° Fahrenheit. In practice, however, a B. T. U. is assumed to be the quantity of heat required to raise one pound of water one degree Fahrenheit.

It might be well to point out here that, as a matter of fact, it requires slightly more than one

British Thermal Unit to produce a change of one degree in one pound of water for temperatures over 63° Fahrenheit, the difference increasing the further the temperature rises above 63°. For temperatures below 62°, it takes slightly less than one British Thermal Unit to produce a change of 1° Fahrenheit in one pound of water, and conversely to the others the difference is greater the more the temperature falls below 63°.

From what has been stated it will be seen that it takes more heat to raise the temperature of one pound of water from 80° to 81° Fahrenheit than it will to raise one pound of water from 40° to 41° Fahrenheit, and conversely, it will take less heat to raise the temperature of one pound of water from 40° to 41° Fahrenheit than it will to raise it from 41° to 42° Fahrenheit. Nothwithstanding this fact, the difference between the amount of heat actually required and the British Thermal Unit commonly used in practice is so slight that it is entirely ignored.

The term temperature is used to denote the sensation of cold or warmth, which is sensible to the touch or is indicated by a thermometer. For instance, if a body be heated and held near the hand, a feeling of warmth is experienced. If it be approached to the bulb of a thermometer the mercury will rise in the stem, thus indicating heat. If the

body be now removed and the heat withdrawn, a feeling of cold is experienced when brought in contact with the hand, and if approached to the bulb of a thermometer, the mercury will drop in the stem.

Sensible Heat.

There are two kinds of heat, known respectively as sensible heat and as latent heat. The heat which is sensible to the touch, or that can be indicated by a thermometer is known as sensible heat. The more sensible heat a body possesses, the hotter it is, and the higher its temperature; the less sensible heat it has, the colder will be the body, and the lower its temperature.

Temperature is not a measure of the quantity of heat a body possesses but may be considered to be a measure of the velocity with which the molecules of matter vibrate to and fro. A small vessel of water might be heated very hot and yet not possess as much heat as a larger vessel of water which is only warm to the touch.

Latent Heat.

If steam at atmospheric pressure has its temperature taken by a thermometer, it will be found that the mercury indicates 212° Fahrenheit. If the steam be now permitted to condense, and the temperature of the water is taken, it will be found to be

of the same temperature as the steam, or 212° Fahrenheit. In condensing the steam into water, however, heat has been given off to the atmosphere and to surrounding objects; clearly then, the steam before condensation possessed some heat which was not sensible to the thermometer. This is true, and this insensible heat is known in practice as latent heat.

Again, take a block of ice which has a temperature of 32° Fahrenheit, and let it melt in a closed box or compartment, watching meanwhile a thermometer in the box or compartment. It will be found that the air of the compartment and the walls have been lowered in temperature, as the ice melts, but the temperature of the ice, also the temperature of the water remain constant at 32° Fahrenheit. It is evident then that when water passes into a solid state it requires latent heat to freeze it, and that this latent heat is given off in the process of melting. Likewise, when water passes from the liquid to the gaseous or vapor state it is with an absorption of heat that remains latent but which is given off when the steam returns to the liquid state.

CIRCULATION IN CIRCUIT.

Instead of circulating locally in a vessel, water can be made to travel continuously through a loop or circuit and back to the point of place of starting. The principle of circulation in circuit

is shown in Fig. 2. If a U-shaped tube be filled with water up to the top of the dotted line *a,* the water will stand in both legs of the loop at exactly the same height. This is due to the fact that the water in both the legs, being of the same temperature and density, will exactly balance each other and remain so in obedience to the law that water at rest will find its own level. If, on the other hand, the tube be connected near the top by the cross-tube shown by dotted lines, the water would finds its level at the highest point to which it could raise, and would remain stationary at that point, and

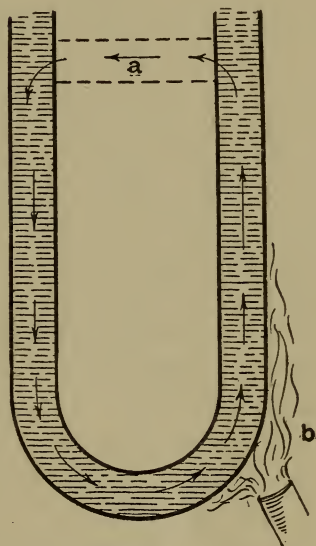

Fig. 2.

so long as the temperature of the water at all points remained unchanged, there would be no perceptible movement of the water within the tube. Should, however, a U-shaped tube, such as shown in the illustration, be filled with water up to the line *a,* and there be no cross-tube connecting the tops of the two legs, and further, should heat be applied

to one of the legs, as at *b*, the water in that leg would become warmer, increase in bulk, and would rise above the level of the line *a*. It would simply be a case of two columns of liquid of different densities, and a greater column of the lighter liquid would be required to balance the heavier liquid.

That portion of the lighter liquid which rises above the line of the heavier liquid, if it had no bounds to confine it, it could flow in any direction; so that if a tube, represented by the dotted lines, were to join the two legs of the U-shaped tube, the excess water in the hot water side would flow to the cold water side of the loop. This transfer of water from the hot water to the cold water side of the loop would upset the balance of the two columns of water and water would flow from the cold water side to the hot water side to replace the loss of weight, thus establishing a circulation in the direction of the arrows, which would continue as long as heat was applied.

VELOCITY OF FLOW OF HOT WATER IN CIRCULATION.

The velocity of flow of water circulating through a loop depends on the height of the loop, the difference between the temperatures of the two columns of water, and the frictional resistance offered to the flow of water. It is obvious that if there is a difference in weight of one ounce between two columns of water two feet high, that if the columns were 20 feet high, there would be a difference of

10x1 ounce, equals 10 ounces pressure, tending to move the water along.

As the hotter water becomes, the more it increases in bulk and the lighter per unit of bulk it becomes, it would naturally follow that the hotter the water was in one leg of the loop, and the colder in the other leg, the greater would be the difference between the weights of the two columns, and the greater would be the pressure-head, tending to move the water through the circuit. Where rapid circulation through a high loop is required, therefore the velocity can be increased by covering the flow pipe with some good non-conducting material and leaving the return pipe uncovered so that radiation can take place from the surface of the pipe, thus lowering the temperature of the water within.

The flow of water through a pipe is impeded by the frictional resistance offered by the walls of the pipe. Naturally, the frictional resistance will vary with the roughness of the inside of the pipe, and the number of bends, branches, and projections. Where circulation is inclined to be sluggish, therefore, the resistance offered to the flow can be materially reduced by using long turn fittings, or making pipe bends where the direction of the pipe is changed, and by reaming the ends of all pipes screwed into fittings, to remove the burr formed by the wheel when cutting the pipe. Lead pipe having no coup-

lings or fittings and presenting a smooth flush interior water-way offers the least resistance of any kind of pipe to the flow of water. Where wrought-iron pipe is used, however, the frictional resistance can be greatly reduced by using recessed drainage fittings. These fittings are recessed so the pipe, when screwed into place, finishes flush on the inside without recess or projection.

CONDUCTION OF HEAT.

In the experiments explained in relation to Figs. 1 and 2, the heat was not applied direct to the water, but to the vessel in which the water was contained. It is quite obvious then that heat had to be transmitted through this containing vessel before it could be absorbed by the water. The passage of heat through an iron vessel in the manner described is due to conduction of heat. Garnot, in his "Physics," explains the phenomena of conduction, as follows: "A hot body is one whose molecules are in a state of vibration. The higher the temperature of a body, the more rapid are these vibrations, and a diminution in temperature is but a diminished rapidity of the vibrations of the molecules. The propagation of heat through a bar is due to a gradual communication of this vibratory motion from the heated part to the rest of the bar. A good conductor is one which readily takes up and transmits the vibratory motion from molecule to mole-

cule, while a bad conductor is one which takes up and transmits the motion with difficulty. But even though the best of conductors the propagation of this motion is comparatively slow. How, then, can be explained the instantaneous perception of heat when a screen is removed from a fire or when a cloud drifts from the face of the sun? In this case, the heat passes from one body to another without affecting the temperature of the medium which transmits it. In order to explain these phenomena, it is imagined that all space, the space between the planets and the stars, as well as the interstices of the hardest crystal, in short, matter of any kind, is permeated by a medium having the properties of matter of infinite tensity, called *ether*. The molecules of a heated body, being in a state of intensely rapid vibration, communicate their motion to the ether around them, throwing it into a system of waves, which travel through space and pass from one body to another with the velocity of light. When the undulations of the ether reach a given body, the motion is given up to the molecules of that body, which, in their turn, begin to vibrate; that is, the body becomes heated. This motion of the waves through the ether is termed radiation, and what is called a ray of heat, is merely a series of waves moving in a given direction."

A familiar example of conduction can be mentioned in the case of an iron bar, one end of which

is thrust into a fire, even though the rest of the bar be screened from the flames so the rays cannot fall on it, in a short time the bar will become warm, then hot from the heat which had crept along from the end that is heated. Another example is the case of a vessel of water, or other fluid, heated by placing the vessel on top of a stove.

THERMOMETERS.

Thermometers made for measuring ordinary temperature, such as obtain in hot water installations, consist of a small glass tube at one end of which is a bulb filled with mercury. This tube is mounted on a background or support, which is divided up into a scale showing the various degrees of temperature. The Fahrenheit thermometer, which is the one generally used in practice, is graduated by finding the point where the mercury stands in the tube when the instrument is placed in melting ice, and marking this point 32°. The point where the mercury stands when the instrument is immersed in water boiling in an open vessel at sea level is then found and marked 212°. The space between these two points is then divided into 180 equal parts, each of which represents one degree Fahrenheit of temperature.

CONDUCTING PROPERTIES OF MATERIALS.

The conducting properties of various materials is of interest in domestic water heating, for two sep-

arate reasons. First, to find a good conductor of heat; and, second, to know a poor conductor of heat. All known substances will conduct heat to a certain extent, but the rapidity of the conduction varies with different substances, some of these materials conduct heat very rapidly, while others conduct heat very slowly, and according to the rapidity with which they conduct heat, the various substances are known as good conductors and as bad conductors.

It can clearly be seen that a material which is a good conductor of heat would make a good material for water backs, and water heaters, if in other ways suitable for the purpose. Of course, a material which is very expensive would not be used for such a purpose, no matter how suitable it might be in other ways, and a material like tin, zinc or lead would not be suitable, on account of their low fusing points, even though they possessed high conductivity. The relative conducting powers of various metals and alloys based on silver, which is considered as 1, can be found in Table I.

Table I.

Heat Conductivity of Metals and Alloys.

Metal.	Relative Conductivity.	Metal.	Relative Conductivity.
Silver,	1.000	Cast Iron,	.170
Copper,	.770	Zinc,	.200
Brass,	.330	Tin,	.150
Steel,	.120	Lead,	.085

It will be noticed from the table that there is a wide range of difference between the conductive

powers of the various metals and alloys and that copper has the highest power of conductivity of any of the substances enumerated which are suitable for plumbing materials.

TABLE OF RELATIVE VALUE OF NON-CONDUCTING MATERIALS.

SUBSTANCE.	VALUE.	SUBSTANCE.	VALUE.
Loose Wool*	3.35	Wood, across grain*	.40 to .55
Loose Lampblack*	1.12	Loam, dry and open	.55
Geese Feathers*	1.08	Chalk, ground, Spanish White	.51
Felt, Hair or Wool*	1.00	Coal ashes	.35 to .49
Carded cotton*	1.00	Gas-house carbon	.47
Charcoal, from cork	.87	Asbestos paper	.47
Mineral wool	.68 to .83	Paste of fossil meal and asbestos	.47
Fossil Meal	.66 to .79	Asbestos, fibrous	.36
Straw Rope, wound spirally*	.77	Plaster of Paris, dry	.34
Rice Chaff, Loose*	.76	Clay with vegetable fibre	.34
Carbonate Magnesia	.67 to .76	Anthracite coal, powdered*	.29
Charcoal from wood*	.63 to .75	Coke, in lumps*	.27
Paper*	.30 to .74	Air space, undivided	.12 to .22
Cork*	.71	Sand	.17
Sawdust*	.61 to .68	Baked clay, brick	.07
Paste of Fossil Meal and Hair	.63	Glass	.05
Wood ashes	.61	Stone	.02

* Combustible and sometimes dangerous.

It often is desirable to cover hot water pipes to keep them from radiating heat, or to prevent them from becoming frozen. Further, a covering material is sometimes desired to prevent pipes from sweating during warm weather. Not only is it desirable to cover water pipes, but under some conditions hot water tanks and even the heaters must be

protected from the atmosphere, and the question then is to find a suitable material of low conductivity instead of one of high conductivity. A table showing the relative value of non-conducting materials will be found on the preceding page.

PRINCIPLE OF HEATING WATER IN A RANGE

The principle by which water in a kitchen range boiler or hot water tank is heated from a water back or water heater, located some distance away, is shown by a reference to Fig. 3. In this apparatus a pipe is taken from the bottom of the tank and extended out a short distance in a horizontal direction, where it terminates in a return bend. From this return bend another pipe is extended up to and connected to the side of the tank, thus forming a continuous loop. If heat be now applied to the return bend as shown in the

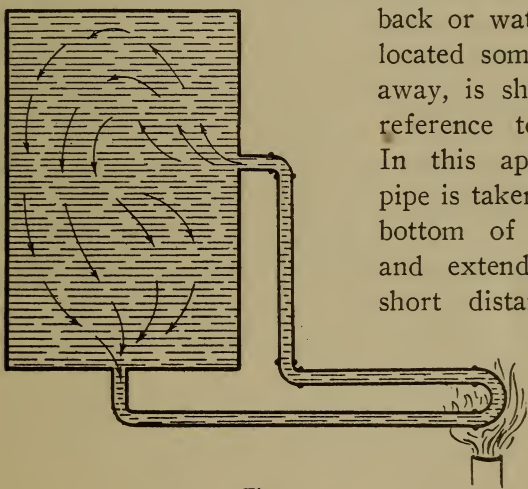

Fig. 3.

illustration, the water within will become heated, become lighter in volume and thus be displaced by a column of water of similar size within the tank. This movement of water, once started, will continue as long as heat is applied to the return bend. To start and maintain such a circulation, however, the pipe leading from the return bend to the side of the boiler must have a rise all of the way. Should this pipe become trapped in any way, the circulation of water would become impeded or entirely stopped, depending on the depth of trap, and if heat were applied to the return bend there would be a rattling, snapping sound that is disagreeable and alarming, if not actually dangerous. This noise is caused by the generation of steam at the return bend and the steam, upon coming in contact with cooler water, after leaving the bend, becomes instantly condensed, thus creating a partial vacuum, which the surrounding water rushes in to fill, with the resulting snapping and banging which is so annoying.

RANGE BOILER CONNECTIONS.

In Fig. 3, the return bend represents the water back in an ordinary kitchen range, the tank represents the kitchen range boiler, and the pipes, the flow and return pipes from the boiler to the water back in the range, and back again, to the boiler. In

Fig. 4, however, is shown the method of connecting up a kitchen range boiler, both to the waterback and to the hot and cold water supply lines. In practice the pipe, which conducts water from the boiler to the waterback, is known as a *flow pipe,* while the pipe which conducts the water back again from the waterback to the boiler is known as a *return pipe.* In an actual installation the boiler stand is only about 18 inches high, so that the waterback in the

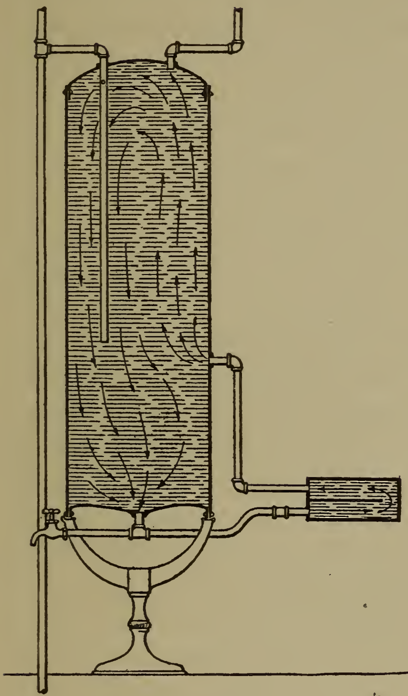

Fig. 4.

range is at higher elevation; consequently, the flow pipe to the waterback must be offset, as shown in the illustration. It is better to make this offset as indicated, by bending the pipe, than to use elbows. Bending the pipe decreases the number of

joints, consequently minimizing the possibility of leaks; is quicker and cheaper to install, and offering less resistance to the flow of water through the pipe. In the waterback the water is heated, flows through the return pipe to the boiler and passes to the top, where it remains on account of its less density than the rest of the water in the boiler. The coldest water is always at the bottom of a hot water boiler, and the hottest water is at the top. Between these two extremes the water is graduated in temperature, the average temperature being found near the center line of the tank.

Any emptying cock is placed on a branch to the flow pipe, so that the boiler can be emptied for cleaning or repairs. Sometimes the boiler has an emptying pipe controlled by a valve or cock and emptying into the drainage system at a point lower down. When this method of construction is employed, it is the better practice to use a ground key cock, for if a valve be used, a slight leak in the seat of the valve might exist without being known, and hot water continually run to waste, while the point of loss would be hard to detect. Many authorities believe that it is a bad practice to connect the emptying pipe from a range boiler into the house drainage system, for during periods when the house is vacant or during temporary absence of the owner from home, the boiler is invariably emptied to prevent possible accident or damage from water should

the pipes or boiler spring a leak, either from weakened structure or bursting from frost. Under such conditions the emptying cock is generally left open and drain air from the soil, waste and vent stacks finds its way into the boiler and perhaps through hot water faucets into the house. If there is a sink in the building at a lower level than the boiler, it is good practice to run the emptying pipe from the boiler to this sink, and let it discharge there, as would a safe waste pipe or a refrigerator water pipe.

The cold water supply pipe to a kitchen range boiler is generally supplied with a stop cock or valve to shut off the water from the boiler, when desired. The cold water supply is connected to the boiler at the top, and a boiler tube, as shown in the illustration, is extended down in the boiler to a point above the level of the side opening to the boiler. The water tube should never be extended below the level of the side outlet to a boiler, for in case water is ever siphoned from the boiler through the cold water supply pipe, a condition which often happens when water is shut off from the building, and a cold water faucet lower down subsequently opened, or when water is shut off from the street mains for repairs, it would empty the water from the boiler to a point below the side outlet and water could not then circulate through the waterback, which would become overheated,

generate steam and cause a rattling, banging noise, even if actual damage did not result. If, on the other hand, the boiler tube does not extend below the level of the side opening and the water becomes siphoned from the boiler to the level of the mouth of the tube, there will still be sufficient water in the boiler to provide for circulation when the return pipe from the waterback is connected to the side outlet of the boiler. In any event it will insure the waterback remaining full of water should siphonage take place.

If the boiler tube were omitted from a range boiler, one of several things might operate to interfere with the proper operation of the apparatus. For instance, if the tube were omitted, cold water from the cold water inlet might follow the line of least resistance from where it enters the boiler, to the outlet for the hot water from the tank. In that event, cold water or alternately cold and hot water would be drawn from the hot water pipes when a faucet was opened. The probability of drawing of cold water from a hot water faucet would be increased in proportion to the nearness the two outlets, the hot and cold water connections, were to each other in the top of the boiler. On the other hand, the further they were spaced apart, the less would be the danger of cold water short-circuiting to the hot water pipe, but a condition almost as disagreeable would result. The capacity for wa-

ter to absorb heat is quite high, and the colder the water the more readily it will absorb heat. Consequently if the boiler tube were omitted, the cold water entering at the top where the water in the boiler is the hottest, would mingle with the hot water, which it would rob of some of its heat, thus interfering with the operation of the hot water apparatus.

Wrought-iron or steel pipe is commonly used for a boiler tube. It is needless to say that whichever material is used, the pipe should be galvanized both inside and outside to prevent as much as possible the rusting of the tube, plain black iron boiler tubes, after being in service for a while become covered with rust which they impart to the water within the boilers thus discoloring the water and rendering it unfit for most domestic uses. The iron rust in water will not only discolor clothes with which it comes in contact but will stain vessels and plumbing fixtures when there is a sufficient amount in the water.

It is better practice to use a boiler tube of brass, copper, Benedict nickel or some equally durable and less objectionable material. Boiler tubes made of wrought iron or steel have often corroded entirely through and broken off, thus not only doing no good but actually being objectionable in the boiler, while in many other cases the vent hole

usually drilled in a boiler tube has been completely choked with a deposit of rust. The cold water pipe to a kitchen range boiler is connected to the top of the boiler and the cold water conducted down through the hot water so that the chill will be taken off the cold water before it is finally discharged into the tank. By employing this means the temperature of the cold water is slightly raised without perceptibly affecting the temperature of the warm water within the tank. A hole is drilled or filed into the side of the boiler tube, near the top; the object of this vent hole is to admit air to break a siphon and thus prevent the water in the tank being lowered below the vent hole.

The hot water pipe is always connected to the top of a kitchen range boiler, because the hottest water in the boiler is at the top.

In many localities the return pipe from the water back to the boiler, instead of being connected to the boiler at the side opening, is carried to the top of the boiler where it is connected either to a special tapping in the boiler provided for that purpose or it is connected to a T branch provided in the hot water pipe close to the boiler head. By connecting a boiler in this manner, hot water can be drawn direct from the water back at the fixtures, while, when the water is not being so drawn it will circulate through the boiler. Heat can be transmitted to the water in a water back much faster than

it can be absorbed under usual conditions. By increasing the velocity of the water, however, the quantity of heat transmitted to the water will be increased, hence, with the flow pipe connected to the top of the boiler, the height of the loop is increased, the velocity accelerated, and more water is heated in a given time than if the flow pipe were connected to the side outlet to the boiler. The method of connecting the return pipe from a water back to the top of a boiler is objected to by some authorities. It is claimed by those, and rightly too, that should the water be siphoned from the boiler to a lower level than the top of the loop, from the water back, a condition which would surely obtain if the water were siphoned to the level of the vent hole in the boiler tube or to the bottom of the boiler tube, that there would be a loss of circulation. While this is true, there would still remain in the boiler such a large volume of water that it is doubtful if any harm could result before the condition of affairs was observed and righted. No damage or accidents, up to the present time, at all events, have been traced to this method of connecting up boilers.

Some plumbers combine the two methods. That is, they not only connect the flow pipe from the water back to the top of the boiler, but they further connect a branch from the flow pipe into the side outlet of the boiler.

MATERIALS FOR RANGE BOILER CONNECTIONS.

Lead pipe, although extensively used for connecting a water back to a boiler, is not the most suitable material for this purpose. The lead expands when heated and upon cooling does not contract to its original length, but sags when run horizontally and unless supported will form traps, thus often causing a rattling in the boiler. Further, the manner in which lead pipes are connected together or are joined to brass water back and boiler couplings is an additional objection to its use. Should at any time the temperature of the pipe become too hot, as, for instance, a fire were started in the range without first turning on the water, or should the pipe become crusted with lime or magnesia to such an extent that water on the inside could not keep the pipe cool, the joints on the lead pipe or between the lead pipe and the water back couplings are liable to pull apart.

Brass, copper and iron pipe are the materials most suited for this purpose. They are strong, rigid, will withstand a great degree of heat without melting and will not sag or stretch out of shape. Of course a certain expansion takes place when the pipes become heated, but upon cooling they return to the normal size and position they were in before being heated. To allow for the expansion of pipes when heated, the range connections between waterback and boiler are or should

be made with room for expansion and contraction. This is done by seeing that pipes are not tight against anything which will interfere with their free movement, and by providing swing joints where pipes would otherwise be rigid. As was pointed out in a former paragraph, the circulation of water between the waterback and boiler is impeded by friction; consequently the ends of brass, copper or iron pipe, where they are screwed into fittings, should be carefully reamed to remove the burr formed by cutting the pipe, and 45° bends, or large radius 90° bends of recess pattern should be used on the flow and return pipe between water-back and boiler. Pipes of smaller diameter than ¾-inch should never be used to connect a water-back or heater to a boiler or storage tank. For connecting an ordinary range boiler to a waterback one-inch pipe will be found the most satisfactory, while for connecting a water heater to a hot water tank, pipes of 1½ inches, 2 inches or even larger should be used, the size depending on the size of the heater and tank.

Use of Check and Safety Valves.

In some localities a check valve is placed in the cold water pipe, which supplies the kitchen range boiler with water. The object of the check valve is to prevent water being siphoned from the boiler in case water is shut off from the street mains or in

the cellar of the building and a cold water faucet at a lower level than the boiler opened. Placing a check valve in the cold water pipe, however, prevents water backing up into the street main when it becomes heated and expands. The expansion of water when heated is no inconsiderable amount, as can be seen in Table 3, and, unless provision is made to relieve the expansion, the boiler or some other part of the system is liable to burst from internal pressure. To relieve the excessive strain from a range boiler, a safety valve is generally provided, when there is a check valve in the water supply, and the escape pipe from the safety vave is extended to a sink or some other point, where in case of a blow off there will be less danger of the hot water being scattered over the kitchen and possibly scald some one. When boilers are subjected to siphonic action, the most serious result ever experienced is the collapse of the boiler from atmospheric pressure. The collapsing of a boiler can be prevented by fitting it with a vacuum valve placed close to the boiler, on a branch to the cold water pipe. The vacuum valve is simply a valve which is held closed by the pressure of water within the mains, but which, when a vacuum is formed within the pipes, will open, thus admitting air to break the vacuum and prevent siphonage of the water from the boiler, with a subsequent collapsing of the boiler.

In some installations both a vacuum valve and a safety valve are provided to protect the boiler from being collapsed by the atmospheric pressure or from being ruptured by internal pressure. Safety valves and vacuum valves are used only in systems which are supplied with water from the city mains, but are unnecessary when water is supplied from a tank within the house.

Expansion Pipe.

In domestic supplies which are obtained from a tank located in the attic of the building, protection both from excess pressure due to expansion of water and from collapsing due to the formation of a partial vacuum in the boiler is provided by means of an expansion pipe. An expansion pipe consists of a pipe extending from the hot water pipe up to and over the house tank, so that any steam or water rising in the pipe can flow into the tank and not wet the floor or ceiling. While not intended for the purpose, yet an expansion pipe serves also as a temperature regulator to control the temperature of the water within a boiler.

The pipe being open to the atmosphere prevents the pressure rising above a certain amount, and as the greatest temperature to which water can be raised depends upon the pressure of the water, it will be seen that this arrangement which prevents a rise in temperature maintains the temperature of the water at an almost uniform degree of not much over 212° Fahrenheit.

TABLE III—COMPARATIVE VOLUME AND DENSITY OF WATER AT DIFFERENT TEMPERATURES

(Calculated by means of Rankine's approximate formula)
(D. K. CLARK.)

Temperature Degrees Fahr.	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 cubic foot Pounds	Remarkable Temperatures
32	1.00000	1.00000	62.418	Freezing Point.
35	0.99993	1.00007	62.422	
39.1	0.99989	1.00011	62.425	Point of maximum density.
40	0.99989	1.00011	62.425	
45	0.99993	1.00007	62.422	
46	1.00000	1.00000	62.418	Same volume and density as at the freezing point.
50	1.00015	0.99985	62.409	
52.3	1.00029	0.99971	62.400	Weight taken for ordinary calculations.
55	1.00038	0.99961	62.394	
60	1.00074	0.99926	62.372	
62	1.00101	0.99899	62.355	Mean temperature.
65	1.00119	0.99881	62.344	
70	1.00160	0.99832	62.313	
75	1.00239	0.99771	62.275	
80	1.00299	0.99702	62.240	
85	1.00379	0.99622	62.182	
90	1.00459	0.99543	62.133	
95	1.00554	0.99449	62.074	
100	1.00639	0.92365	62.022	Temperature of condenser water.
105	1.00739	0.99260	61.960	
110	1.00889	0.99119	61.868	
115	1.00989	0.99021	61.807	
120	1.01139	0.98874	61.715	
125	1.01239	0.98808	61.654	
130	1.01390	0.98630	61.563	
135	1.01539	0.98484	61.472	
140	1.01690	0.98339	61.381	
145	1.01839	0.98194	61.291	
150	1.01889	0.98050	61.201	
155	1.02164	0.97882	61.096	

TABLE III—Continued

Temperature	Comparative Volume	Comparative Density	Weight of 1 cubic foot	Remarkable Temperatures
Degrees Fahr.	Water at 32° = 1	Water at 32° = 1	Pounds	
160	1.02340	0.97714	60.991	
165	1.02589	0.97477	60.843	
170	1.02690	0.97380	60.783	
175	1.02906	0.97193	60.665	
180	1.03100	0.97006	60.548	
185	1.03300	0.96828	60.430	
190	1.03500	0.96632	60.314	
195	1.03700	0.96440	60.198	
200	1.03889	0.96256	60.081	
205	1.0414	0.9602	59.93	
210	1.0434	0.9584	59.82	
212	1.0444	0.9575	59.76	Boiling point by formula
212	1.0466	0.9555	59.64	Boiling point by direct measurement.
230	1.0529	0.9499	59.26	
250	1.0628	0.9411	58.75	
270	1.0727	0.9323	58.18	
290	1.0838	0.9227	57.59	
298	1.0899	0.9175	57.27	Temperature of steam of 50 lbs. effective pressure per square inch.
338	1.1118	0.8994	56.14	Temperature of steam of 100 lbs. pressure per square inch.
366	1.1301	0.8850	55.29	Temperature of steam of 150 lbs. pressure per square inch.
390	1.1444	0.8738	54.54	Temperature of steam of 205 lbs. effective pressure per square inch.

CHECK VALVES FOR COLD WATER SUPPLY.

There are two types of check valves used around hot water boilers to prevent a back-flow to the

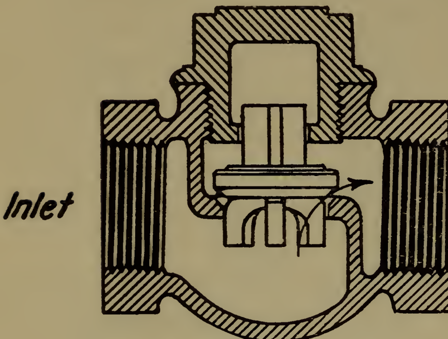

Fig. 5.

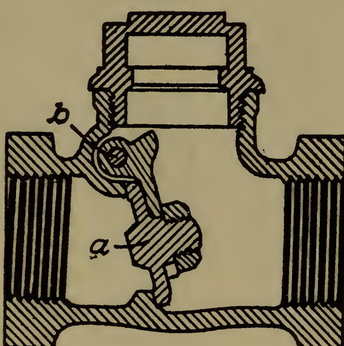

Fig. 6.

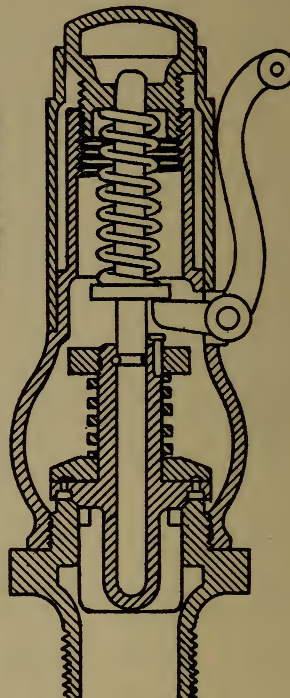

Fig. 7.

water mains; they are known respectively as *lift check valves* and *swing check valves.* A lift check valve is shown in Fig. 5. When passing through

this type of valve, water flows through the inlet, raises the valve disk from its seat and flows in the direction of the arrow toward the outlet. In case the pressure is greater on the outlet side of the valve the disk is seated the more firmly by the pressure and no water can escape through unless the valve leaks. In the swing check valve, shown in Fig. 6, there is less resistance offered to the flow of water than in the lift check valve. This makes the swing check valve better suited for use in places where the water pressure is very low, or in circulating circuits where the flow is sluggish. When water flows into the outlet end of this valve, which is at the left side, the pressure swings the gate *a* on the hinge *b* and permits the water to flow through, but closes immediately should a back pressure set in toward the opposite direction.

A safety valve, such as may be used over a hot water boiler in connection with a check valve is shown in section in Fig. 7. In this device, the disk is held on its seat by means of a spring which can be set to open at any desired pressure. Usually the spring is adjusted to open at a pressure of from 10 to 15 pounds above the normal pressure of the water supply. A lever at the right-hand side of this safety valve is provided so the valve can be tested from time to time to see that it is not stuck to the seat. By attaching a chain to the lever a person standing on the floor of the kitchen can try

the valve at pleasure. Safety valves which are kept closed by means of a weight or ball of iron are seldom used for this purpose, particularly when the hot water boiler is located in the kitchen.

BOILING POINTS OF WATER.

By the boiling point of water is meant the temperature at which ebullition takes place. The boiling point of water, which is also the temperature at which steam forms, depends upon the elevation with regard to sea level when the vessel is uncovered, or to the pressure when the vessel is enclosed. In other words, it may be said that the temperature at which water boils varies with the pressure. Thus, in a vacuum of 13.69 pounds below atmospheric pressure, water boils at a temperature of 102° Fahrenheit, which is but slightly above blood heat. At atmospheric pressure, at sea level, which is generally taken to be 14.7 pounds per square inch, water boils at a temperature of 212 degrees Fahrenheit, which is likewise the temperature at which steam forms in an open vessel. At 15.31 pounds above atmospheric pressure, water boils at a temperature of 250° Fahrenheit. In short it may be said that the temperature of boiling water and the temperature of steam in contact with the water are always equal, and the pressure of boiling water and the pressure of steam in contact are always equal. Further, there is a certain defi-

nite relation between the pressure and temperature of the water and steam in contact. The pressure cannot be increased without increasing the boiling

TABLE IV.

Absolute Pressure in pounds per square inch	Boiling point of water, degrees Fahrenheit	Ratio of volume of steam to volume of equal weight of distilled water at temperature of maximum density	Pressure above vacuum in pounds per square inch	Boiling point of water, degrees Fahrenheit	Ratio of volume of steam to volume of equal weight of distilled water at temperature of maximum density
1	2	3	1	2	3
1	102.018	20623	46	275.704	563.0
2	126.302	10730	48	278.348	540.9
3	141.654	7325	50	280.904	520.5
4	153.122	5588	52	283.381	501.7
5	162.370	4530	54	285.781	484.2
6	170.173	3816	56	288.111	467.9
7	176.945	3302	58	290.374	452.7
8	182.952	2912	60	292.575	438.5
9	188.357	2607	62	294.717	425.2
10	193.284	2361	64	296.805	412.6
11	197.814	2159	66	298.842	400.8
12	202.012	1990	68	300.831	389.8
13	205.929	1845	70	302.774	379.3
14	205.604	1721	72	304.669	369.4
14 69	212.000	1646	74	306.526	360.0
15	213.067	1614	76	308.344	351.1
16	216.347	1519	78	310.123	342.6
17	219.452	1434	80	311.866	334.5
18	222.424	1359	82	313.576	326.8
19	225.255	1292	84	315.250	319.5
20	227.964	1231	86	316.893	312.5
22	233.069	1126	88	318.510	305.8
24	237.803	1038	90	320.094	299.4
26	242.225	962.3	92	321.653	293.2
28	246.376	897.6	94	323.183	287.3
30	250.293	841.3	96	324.688	281.7
32	254.002	791.8	98	326.169	276.3
34	257.523	748.0	100	327.625	271.1
36	260.883	708.8	105	331.169	258.9
38	264.093	673.7	110	334.582	247.8
40	267.168	642.0	115	337.874	237.6
42	270.122	613.3	120	341.058	228.3
44	272.965	587.0			

point of the water and the temperature at which steam forms; and, conversely, the temperature of

the water cannot be increased without increasing the pressure of the water and of the steam with which it is in contact. This is important to know for when the pressure carried in the city water mains is known, the temperature at which water will boil in the water back and hot water tank can easily be determined. For instance, if the pressure of water in the street mains be 100 pounds per square inch, a common pressure for city water mains, the temperature corresponding to that pressure, at which the water will boil, will be about 337° Fahrenheit. The relative pressures and temperatures of boiling water and steam in contact, from about 15 pounds vacuum to 105 pounds gauge pressure, can be found in Table IV. In this table the pressures are stated as absolute pressures so that 14.69 pounds must be deducted from each reading to determine the gauge pressure at which water boils. In addition to the boiling points and corresponding pressures, the table gives the ratio of volume of steam, to a volume of equal weight of pure water, when converted into steam and subjected to the pressure indicated. For instance, one pound of water when converted into steam, and subjected to an absolute pressure of 46 pounds per square inch, would expand in volume to 563 times the bulk of the original pound of water.

Pressure of Water.

In dealing with water pressures, it is well to know just what is meant by the various terms. There are two kinds of pressures used in hydraulics, gauge pressure and absolute pressure. It is well known that the atmosphere exerts, or is subjected to a pressure of approximately 14.7 pounds per square inch, and when pressure is calculated from the zero pressure of atmosphere, the pressure is absolute; and the ordinary atmospheric pressure, everything is subjected to, is rated at 14.7 pounds per square inch. Ordinarily, however, the pressure of the atmosphere is ignored, and pressure readings are taken from the 14.7 point, which is considered zero. Thus it is that the gauge pressure takes no account of the pressure of the atmosphere, and gauges indicate only the additional pressure above atmospheric. To find the absolute pressure of

Fig. 8.

water, therefore, when gauge pressure is given, add 14.7 pounds to the readings of the gauge. When absolute pressures are given they can be converted into gauge pressures by substracting 14.7 pounds from the absolute pressure.

The pressure of water in closed systems is generally indicated by means of a pressure gauge. The construction and principle of operation of a pressure gauge can be seen in Fig. 8. The dial face has been removed in this illustration to show the interior construction and operation of the apparatus. The construction of the gauge is as follows: A bent tube *a* of elliptical cross-section, made of a suitable metal of the required elasticity, has its bottom end firmly attached to the gauge case and its upper end free to move. To the upper end is attached a lever, *b*, which is connected to a pointer in front of the dial face, in such a manner that any movement of the tube will be indicated by the pointer on the graduated index on the face of the gauge. The gauge operates on the principle that if a bent tube of elliptical cross-section is subjected to internal pressure, the force exerted will tend to straighten the tube. This is due to the fact that a force exerted within a tube of elliptical cross-section tends to make it take a circular form; to do so the inner arc of the bent tube must lengthen and the outer arc shorten, and the combined effort will straighten the tube in direct proportion to the

pressure exerted. The straightening of the tube imparts a movement to the register hand which in turn indicates on the face of the gauge the intensity of the pressure.

HOW TO DETERMINE PRESSURE OF WATER.

Without the use of a gauge the pressure of water can be determined, when the height of the column is known. One foot depth of water, one inch square, weighs approximately .434 of a pound, and by multiplying the depth of water in feet by the constant .434 will give the pressure per square inch on the base of the column of water. Pressure is but another name for weight when applied to water and instead of calculating the pressure or weight of water, it may be determined for heads from 1 foot in depth to 240 feet in depth, by referring to Table V.

TRANSMISSION OF HEAT TO WATER.

The amount of heat that can be transmitted to water, depends on the volume of the fluid and its temperature. There is, however, a certain quantity of heat which can be transmitted to a unit volume of water and the amount of heat which can be transmitted to the unit volume varies with and is constant for the different temperatures. Furthermore, the quantity of heat, or the number of B. T. U. required to raise the temperature of a unit volume of water to the boiling point is constant and applies to every case. For instance, it requires

TABLE V.

PRESSURE OF WATER AT VARIOUS HEADS.

Feet Head	Pressure per Square Inch	Feet Head	Pressure per Square Inch	Feet Head	Pressure per Square Inch	Feet Head	Pressure per Square Inch	Feet Head	Pressure per Square Inch
1	0.43	49	21.22	97	42.01	145	62.81	193	83.60
2	0.86	50	21.65	98	42.45	146	63.24	194	84.03
3	1.30	51	22.09	99	42.88	147	63.67	195	84.47
4	1.73	52	22.52	100	43.31	148	64.10	196	84.90
5	2.16	53	22.95	101	43.75	149	64.54	197	85.33
6	2.59	54	23.39	102	44.18	150	64.97	198	85.76
7	3.03	55	23.82	103	44.61	151	65.40	199	86.20
8	3.46	56	24.26	104	45.05	152	65.84	200	86.63
9	3.89	57	24.69	105	45.48	153	66.27	201	87.07
10	4.33	58	25.12	106	45.91	154	66.70	202	87.50
11	4.76	59	25.55	107	46.34	155	67.14	203	87.93
12	5.20	60	25.99	108	46.78	156	67.57	204	88.36
13	5.63	61	26.42	109	47.21	157	68.00	205	88.80
14	6.06	62	26.89	110	47.64	158	68.43	206	89.23
15	6.49	63	27.29	111	48.08	159	68.87	207	89.66
16	6.93	64	27.72	112	48.51	160	69.31	208	90.10
17	7.36	65	28.15	113	48.94	161	69.74	209	90.53
18	7.79	66	28.58	114	49.38	162	70.17	210	90.96
19	8.22	67	29.02	115	49.81	163	70.61	211	91.39
20	8.66	68	29.45	116	50.24	164	71.04	212	91.83
21	9.09	69	29.88	117	50.68	165	71.47	213	92.26
22	9.53	70	30.32	118	51.11	166	71.91	214	92.69
23	9.96	71	30.75	119	51.54	167	72.34	215	93.13
24	10.39	72	31.18	120	51.98	168	72.77	216	93.56
25	10.82	73	31.62	121	52.41	169	73.20	217	93.99
26	11.26	74	32.05	122	52.84	170	73.64	218	94.43
27	11.69	75	32.48	123	53.28	171	74.07	219	94.86
28	12.12	76	32.92	124	53.71	172	74.50	220	95.30
29	12.55	77	33.35	125	54.15	173	74.94	221	95.73
30	12.99	78	33.78	126	54.58	174	75.37	222	96.16
31	13.42	79	34.21	127	55.01	175	75.80	223	96.60
32	13.86	80	34.65	128	55.44	176	76.23	224	97.03
33	14.29	81	35.08	129	55.88	177	76.67	225	97.46
34	14.72	82	35.52	130	56.31	178	77.10	226	97.90
35	15.16	83	35.95	131	56.74	179	77.53	227	98.33
36	15.59	84	36.39	132	57.18	180	77.97	228	98.76
37	16.02	85	36.82	133	57.61	181	78.40	229	99.20
38	16.45	86	37.25	134	58.04	182	78.84	230	99.63
39	16.89	87	37.68	135	58.48	183	79.27	231	100.06
40	17.32	88	38.12	136	58.91	184	79.70	232	100.49
41	17.75	89	38.55	137	59.34	185	80.14	233	100.93
42	18.19	90	38.98	138	59.77	186	80.57	234	101.36
43	18.62	91	39.42	139	60.21	187	81.00	235	101.79
44	19.05	92	39.85	140	60.64	188	81.43	236	102.23
45	19.49	93	40.28	141	61.07	189	81.87	237	102.66
46	19.92	94	40.72	142	61.51	190	82.30	238	103.09
47	20.35	95	41.15	143	61.94	191	82.73	239	103.53
48	20.79	96	41.58	144	62.37	192	83.17	240	103.96

212 B. T. U. to raise the temperature of one pound of water from zero to 212° Fahrenheit, and it will take 106 B. T. U. to raise to the boiling point

TABLE VI.

B. T. U. AT DIFFERENT TEMPERATURES.

Temperature. Degrees Fahr.	Number of B. T. U., reckoning from 0°.	Number of B. T. U. required to raise the Temperature of the Water to Boiling Point, 212° Fahr.
35	35.000	177.900
40	40.001	172.899
45	45.002	167.898
50	50.003	162.897
55	55.006	157.894
60	60.009	152.891
65	65.014	147.886
70	70.020	142.880
75	75.027	137.873
80	80.036	132.864
85	85.045	127.855
90	90.055	122.845
95	95.067	117.833
100	100.080	112.820
105	105.095	107.815
110	110.110	102.790
115	115.129	97.771
120	120.149	92.751
125	125.169	87.731
130	130.192	82.708
135	135.217	77.683
140	140.245	72.655
145	145.275	67.625
150	150.305	62.585
155	155.339	57.561
160	160.374	52.526
165	165.413	47.487
170	170.452	42.447
175	175.497	37.403
180	180.542	32.358
185	185.591	27.309
190	190.643	22.257
195	195.697	17.203
200	200.753	12.147
205	205.813	7.087
210	210.874	2.016

water which has a temperature of 106° Fahrenheit. The number of B. T. U. contained in one pound of water at different temperatures, also the number of B. T. U. required to raise one pound of water, from different temperatures to the boiling point at atmospheric pressure, may be found in the table on the preceding page.

HEATING WATER BY KITCHEN RANGES

The water stored in range boilers, for use in the home, is generally heated in a water back, located in the firebox of the kitchen range. In this sense the term waterback is used to indicate the apparatus used for heating water, regardless of its location in the firebox. Some ranges have the heating coil casting located at the front of the firebox, in which case, strictly speaking, they are water fronts. In some the casting is at the end of the firebox, in which case they are water ends. Other ranges have the casting located at the back of the firebox, in which case they are water backs. For convenience in referring to them, however, they will be referred to indiscriminately as waterbacks, as the principles of installation and the connections to the differently located castings are all the same.

A waterback is simply a hollow casting with two tapped openings for connecting pipes to. The casting, being located in the firebox, absorbs heat from the flames, and the hot gases coming in contact with it, which in turn is transmitted to the water within the casting. As this water becomes heated it likewise becomes lighter and is displaced by colder water, thus setting up a circulation between the waterback and the boiler. Sometimes the waterback

has a partition cast horizontally part way across it, so that the water will have to flow the full length of the casting. A waterback, such as is used for kitchen ranges, is shown in Fig. 9. This waterback

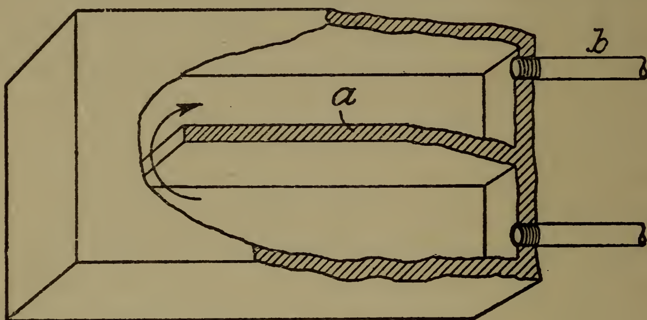

Fig. 9.

is made with a partition, *a,* cast part way across it, so that the circulating water will have to flow in the direction of the arrow. If it were not for this partition some water could short circuit from the inlet to the outlet, without becoming thoroughly heated. The opening for the flow pipe, *b,* should be tapped close to the top wall of the waterback, so that the very hottest water in the casting can flow out, and not be trapped to become converted into steam.

Waterbacks are made much thicker than would seem necessary to withstand the pressure of water to which they are subjected, but it must be remembered that when manufactured nobody knows where

or under what conditions they will be used, consequently they are made to withstand the worst possible use. The casting might be used in connection with a low pressure job, where it will never be subjected to a greater internal pressure than 20 pounds per square inch, or it might be used in a locality where the pressure on the street mains is over 100 pounds per square inch, and when, owing to deposits of lime, the waterback becomes partly or wholly obstructed and becomes then subjected to much severer use. Furthermore, the casting is subjected to severe stresses at times, owing to the cold water within the waterback and the intense fire outside. To provide for all these various stresses to which waterbacks are exposed, they are designed to withstand an ultimate pressure of 700 pounds per square inch. Even this strength is not sufficient in extreme cases of neglect and we often hear or read of waterbacks bursting with disastrous results. The damage done by a bursting waterback can easily be realized, when it is considered that the bursting pressure must become 700 pounds per square inch.

The most common cause of waterbacks bursting is freezing of the water in the waterback, or connections. Consequently, where ranges are exposed in cold places, during winter weather, extra precautions should be observed to see that the water pipes do not freeze, and if the fire in the range goes out during the night, before firing up in the morning,

it is well to make sure that the waterback, flow and return pipes are free from ice. Plumbers installing hot water apparatus in cold places should caution their customers with regard to the danger from frost.

It would seem needless to remark that valves, cocks or checks of any kind should not be placed either in the flow or return pipe to a boiler; yet, so many installations have valves in them, that the objection to them cannot be too forcibly pointed out. If for any reason a stop cock or valve in one of these installations should become closed through ignorance, carelessness or neglect, steam would form in the waterbacks, and if the pressure became sufficient, burst the casting.

The size of a waterback is the heating surface it contains in square inches, measuring only that side, or side and edge which are exposed to the fire. The average size of waterback contains about 110 square inches and will heat the water in a water tank containing 40 gallons of water, for an ordinary family. The waterbacks in ranges for hotels, restaurants, clubs, and like institutions are made larger than the waterbacks to family ranges and will heat more water, the capacities being determined in each case by the range manufacturer.

INCRUSTATION OF WATERBACKS.

The rock formation of the surface of the earth seems to be largely limestone, and water passing

through it becomes impregnated with this lime to such an extent that it not only refuses to work in harmony with the compound known as soap, but it so incrusts waterbacks, coils in heaters and furnaces, flues in steam boilers and connecting pipes, that in a comparatively short time they clog up or become ineffective.

To overcome this characteristic of limestone water has been a long and ardent study and an endless experiment. The observing mechanic, as well as the careful housewife, has long since discovered that one of the greatest nuisances and most expensive items is this adhesion of lime from hard water. It is stated that ninety per cent of the inland cities are supplied with hard water for domestic use.

Water impregnated with hardenable carbonates and sulphates of lime, magnesia and other incrusting minerals, cause not only loss of full value of heat and steam, but also frequent repair bills. If scale can be prevented, there is a large saving of fuel. It is stated that an eighth of an inch of scale adds nearly one-fourth to the fuel bill.

When a waterback becomes so incrusted with lime, magnesia and other incrusting minerals, that there is danger of a complete stoppage, or when the incrustation becomes so thick on the walls of the casting that sufficient heat is not transmitted to the water, the waterback must be taken from the

fire-box and cleaned or provided with an apparatus that will clean it.

To do so, the water is first shut off, the water emptied from the boiler and the pipes then disconnected, after which the casting can be lifted out of the range fire-box. The water is emptied from the boiler by opening the draw-off cock at the bottom of the boiler and turning on a hot water faucet at some fixture in the building, so that air will be admitted to the boiler to replace the water withdrawn. If air is not admitted to the boiler no water will run out, but, on the contrary, it will remain air-bound within the tank, just the same as if a bottle of water be inverted. Sometimes the hot water pipes in a building are trapped, and air cannot flow into the boiler when a hot water faucet is opened. When such is the case the hot water supply coupling on top of the boiler should be uncoupled to let in air.

Sometimes the incrustation inside the waterback is flaky, and can easily be scaled off or detached by pounding the casting on all sides with a hammer and jarring the lime out of the pipe openings by dropping it, the open end down, on a plank or block of wood provided for that purpose. When the scale is not so easily removed, particles can be detached by means of a long slender chisel, worked through the openings to break up the scale.

Sometimes the incrusting material is of such quality, or has been baked so hard to the sides of the waterback that it cannot be reached by ordinary means; then it becomes necessary to provide the waterback with an apparatus that will soften the water ere it enters the waterback, and the old scale will then gradually come off as the water disintegrates the lime.

Preventing the Incrustation of Waterbacks.

By making special provision against the deposits of lime, magnesia and other incrusting minerals in waterbacks and coils, the incrustation can be entirely checked where water that is very hard must be heated. To prevent incrustation, the hard water must be neutralized or partly softened ere it enters the waterback or boiler. The water may be treated by a special apparatus such as shown in Figure 10. With this apparatus, which is automatic in operation, the feeder or chamber is supplied with a brick, a water softening composition, the supply being automatically controlled by two valves on the apparatus, which can be regulated to such a point that all the water is neutralized before it enters the heating apparatus.

The water softening composition converts the sulphates and carbonates in the water into phosphates, which cannot harden, making the formation of scale an impossibility. This composition is harmless when

used in the water for culinary, drinking or toilet purposes, or, in other words, the water can be used for the same purposes as before the apparatus was installed.

For residences and small institutions, where a 30 or 40 gallon range boiler is installed, the above apparatus should be connected in the cold water supply pipe in basement leading to range boiler as

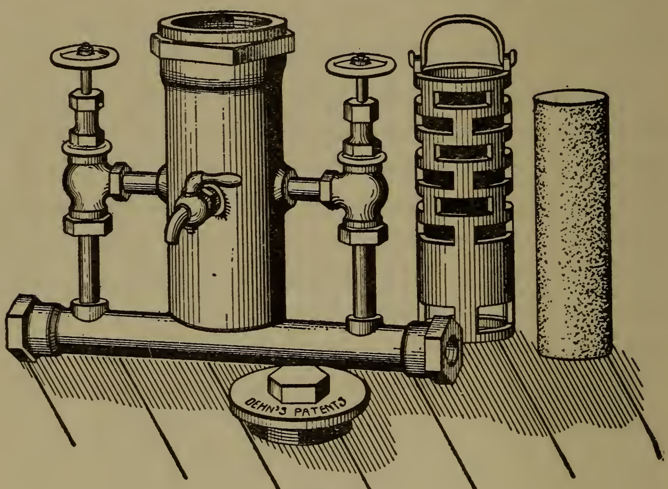

Fig. 10.

shown in Fig. 11. By connecting the apparatus in the cold water pipe all the cold water will be neutralized before entering the boiler and the water will circulate through the apparatus only when hot water is being drawn from the range boiler; hence it will be impossible to have any lime, magnesia or other incrusting minerals accumulate in the pipe connection or boiler.

For large institutions such as hotels, restaurants, hospitals, barber shops, city and county institutions,

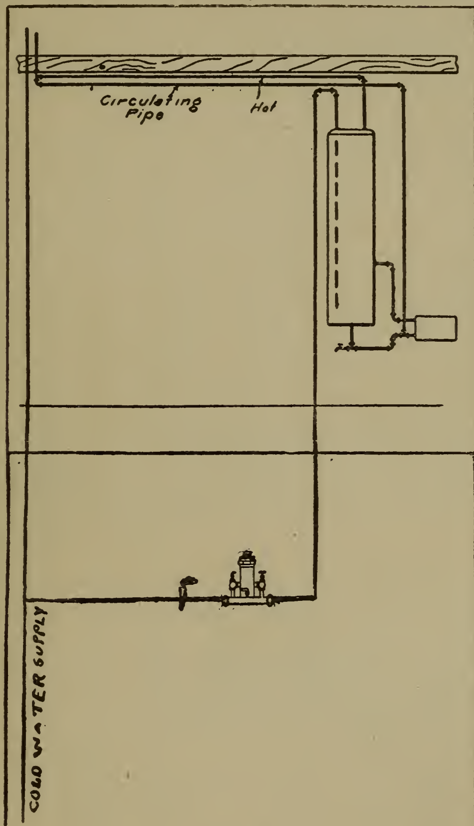

Fig. 11

where large quantities of water are consumed daily, the apparatus should be connected in the feed or cold water pipe to heater, as shown in Fig. 11a.

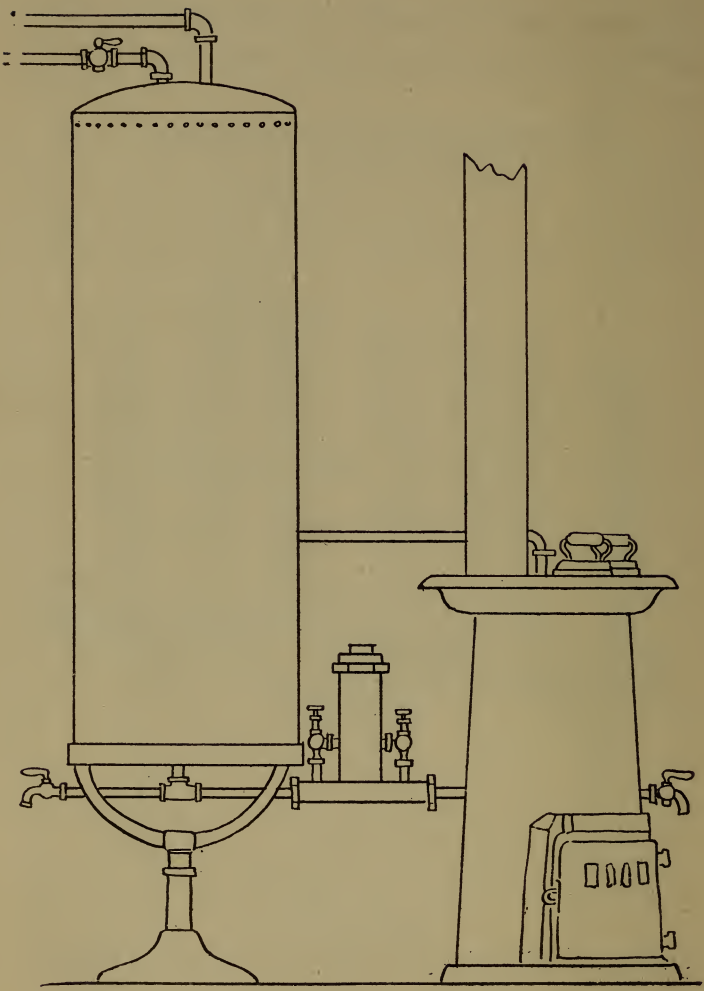

Fig. 11a.

It will be seen that the range boiler and range have the usual pipe connections, and that the apparatus is connected in the feed or cold water pipe. After the apparatus has been installed and the cold water turned into the system, open the hot water faucets to allow the grease and dope to leave the system (which usually enters the system when cutting the pipe and making new connections).

When the water is clear and free from grease and dope, turn the two valves off on the apparatus, open the drain cock at bottom of apparatus, then unscrew cover from the top of apparatus, drop a brick of water-softening composition into the basket in feeder, screw cover down tight, close drain cock, then open the two valves with one revolution, when all will be ready for action as soon as fire is started in the range.

It is said that one brick water-softening composition will neutralize from 3,000 to 5,000 gallons of hard water, depending upon the acidity of the water. It can be ascertained by the hardness of the water if the brick is consumed. It is important to have a fixed time for charging the apparatus. The sediment cock at the bottom of the range boiler should be opened at least once a week to blow out the sediment and keep the water from getting roily.

DEPOSITS OF MUD IN WATERBACKS AND BOILERS.

In many localities, particularly on the banks of turbid streams, or rivers, from which the municipality receives its supply of water, so much mud and sediment is carried in suspension that the water presents a very muddy appearance. When kept constantly stirred up by the agitation incident to flowing through pipes, the mud remains suspended in the water, but if allowed to remain quiescent for a few hours, as for instance, in hot water boilers, and closet tanks over night, a large percentage of the mud will settle to the bottom, where if not again stirred up, it will remain until removed by some means. By using a properly constructed mud collector or draw-off in connection with a boiler, the sediment can be separated from the water and drawn off at intervals without stirring up the mud, consequently, the hot water supply, when such provision is made, will be clearer than it otherwise would, and the waterback will be protected from a deposit of mud, which, when baked on becomes so hard that it is difficult to remove. Mud, it might be stated, cannot be treated like hardness of water, to prevent incrustation, but the only way is to remove as much as possible of the mud content of the water. A simple means of accomplishing this

is to use a device similar to that shown in Fig. 12. To use this device, the bottom connection to the boiler must be larger than the standard size. Into this enlarged opening the mud connection is screwed. The connection consists of an enlarged pocket or fitting, with the return pipe connection to the waterback passing up through the center of it to a distance of several inches above the level of the bottom of the boiler. Around this stand pipe is an annular space through which mud, following the natural slope of the bottom of the boiler can settle down into the mud pocket. It will be noticed that when such a fitting is used, there is little or no danger of the mud becoming

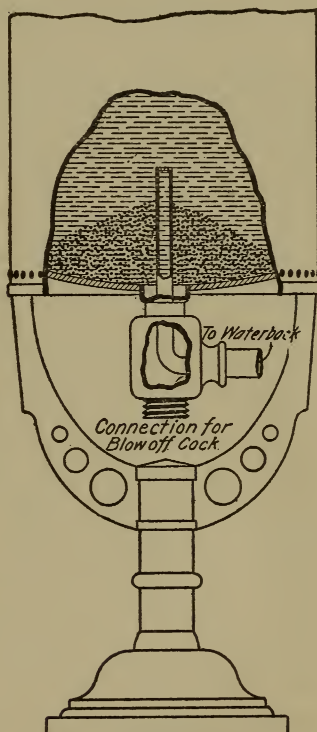

Fig. 12.

stirred up by the circulation of water between the waterback and boiler, unless through carelessness in not drawing off the mud occasionally through the

blow-off connection, it is allowed to accumulate until it reaches a point above the top of the return pipe to the waterback.

PIPE COILS FOR HEATING WATER.

Some cooking stoves and ranges are not provided with waterbacks for heating water, and sometimes it is desirable to heat water in an ordinary heating stove, furnace, or other type of heater. Under such conditions heating coils, made of pipe, are used to supply the deficiency of waterback or water jacket. Usually pipe coils are made of plain, wrought-iron, or steel pipe, put together with ordinary steam fittings generally of the return bend pattern. In other cases the coil is made of copper or brass tubing, bent to fit its final resting place in the firebox. Whatever the material used, the ends are threaded and made long enough to project through the side of the cooking range or heaters so that they can be connected to the flow and return outlets of the boiler. Pipe coils are usually made and installed by the plumber or steam fitter, and great care must be exercised in doing this work, if satisfactory results are to be obtained. The first precautions must be observed in locating and drilling the holes through the side of the firebox, to get them in their right places, and not to break the thin casting, which is easily cracked.

Good judgment and extreme care must also be exercised in placing a coil within a firebox, to see that it does not in any way interfere with or derange the other functions of the range or heater. There is less danger of this in a heater than there is in a cooking stove or range. The principal objection to placing a heating coil in a range is the fact that its effect on the draft of the stove or heating capacity of the oven can never be foretold. As a consequence, ovens are often spoiled for baking and roasting by placing a waterheating coil in the range, if not designed to accommodate one, or by improperly installing a coil in a range, that if properly installed would work satisfactorily.

SPECIAL WATER HEATERS.

Where large quantities of water must be heated, such as in apartment houses, clubs, hotels, hospitals, bathing establishments, swimming pools, baptistries and for other purposes which might arise in practice, special heaters are required, unless the water is heated by steam. For this purpose, what might be called a water-jacketed stove is used. One type of such water heater is shown in Fig. 13. It consists of a firebox encased with a double casing between the walls of which water can circulate and absorb heat from the hot coals, and gases against the inner casing. Water enters this water jacket as the space formed by the two walls is called, through an opening near the bottom, and after becoming heated, passes out through the hot water opening near the top of the casing. The water heating part

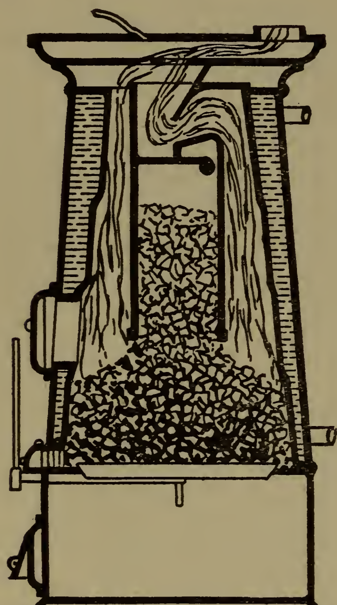

Fig. 13.

of the apparatus is mounted on an ash pit and over a coal grate, so that fuel can readily be burned within.

Water heaters are made of cast iron and of steel, and in capacities ranging from 50 to 600 gallons per hour. Larger sectional heaters are made with capacities up to several thousand gallons of water per hour. Water heaters are also made for hand-feed and for magazine feed. The one shown in the illustration is a magazine feed heater. The magazine feeding apparatus consists simply of a tube or coal chute in the center of the heater which will hold several hours supply of coal, which is automatically fed to the fire as required. A magazine fed heater can be converted into a hand fed heater by removing the magazine, but conversely, a hand fed heater cannot be converted into a magazine fed heater, because no provision is made for a magazine in the hand fed types.

Connections to Water Heaters.

The connections to water heaters vary in size according to the capacity of the heater. Heaters having capacities of 50 gallons per hour usually have 1¼-inch connections. Those having 100 gallons capacity have 1½-inch connections, and heaters of 150 gallons capacity have 2-inch connections.

The quantity of water that can be heated by a water heater depends on the area of the grate surface. It is commonly accepted in practice that one

square foot of grate surface will heat from 35 to 40 U. S. gallons of water per hour from ordinary temperature to about 200° Fahrenheit. So this will be found a safe allowance for ordinary purposes when the amount of hot water required is known. It might be well to add, in passing, that a water heater to give good service, should have a good, well proportioned flue. There is an intimate relation between the size or area of grate in a water heater and the area of smoke flue to which the heater is connected, and unless this relation is maintained and the two proportioned to each other, although the heater is otherwise rightly proportioned, it will not give the degree of satisfaction that might be expected. If the smoke flue is small, crooked and rough inside, the draft will be checked and less air will be brought in contact with the fuel than would be the case if the flue were large, straight and smooth inside. In operating the heater there will likewise be a marked difference. With a good smoke flue the fire will respond readily to the manipulation of the drafts, springing up and burning brightly as soon as they are opened, while with a small flue, the fire at its best will be sluggish. In practice it is customary to allow for smoke flue one-eighth of the sectional area of the grate surface. That would be equal to 18 square inches area in the smoke flue for each square foot of grate surface.

Having provided a good smoke flue for the water heater, no other smoke pipes should be permitted to connect to it, nor should other openings to the flue be allowed. Two fires on one smoke flue will spoil the draft so that neither fire will be satisfactory.

GARBAGE BURNING WATER HEATERS.

In many institutions like asylums, poor farms, hospitals and sanitariums there is an accumulation of combustible mterials which must be disposed of, as well as a greater or less amount of garbage, in the shape of refuse of vegetables prepared for meals, which would become a nuisance if not cared for in a sanitary manner. In such institutions there generally is plenty of help to look after fires, and garbage burning water heaters may be used for heating water, using combustible materials like paper and

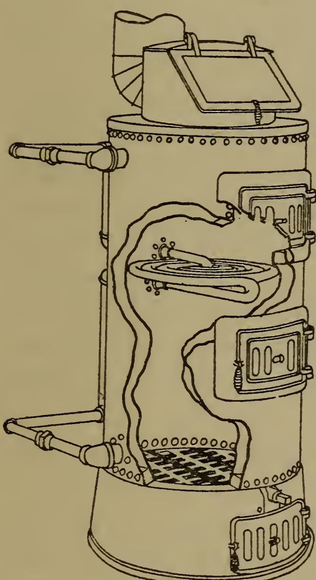

Fig. 14.

scraps of wood for fuel, and consuming the garbage from the institution at the same time. In case it is desired to dispose of papers and other combustible materials otherwise, coal may be used for fuel in the garbage burning heater, the same as in an ordinary water heater. A garbage burning heater is shown in Fig. 14. It differs from an ordinary water heater principally in having a shelf made of pipe coils, through which water circulates and on which garbage may be dumped to dry out and be burned.

HEATING WATER WITH GAS.

Gas has come into such general use, within recent years, for cooking of meals and other household purposes, that it is not surprising to find it invading the field of coal, in the heating of water for domestic use. The value of gas as a fuel lies in the fact that as soon as it is lighted, the maximum degree of heat is immediately developed, and this heat can be applied at any convenient point in a heating apparatus. On account of the heat immediately reaching its maximum degree, as soon as the gas is lighted, and the fact that a certain percentage of the heat contained in gas is not required to produce a draft to promote combustion, as in the case of coal, ordinary illuminating gas can easily compare with coal in economy and can be used in some installations where coal would be too expensive. Ordinary illuminating gas contains between 650 and 700 available B. T. U.'s per cubic foot, and this heat is suf-

ficient to raise the temperature of one gallon of water from ordinary temperature, which is 62 degrees Fahrenheit, to between 110 and 120 degrees Fahrenheit; as 120 degrees Fahrenheit is as warm as water is required for bathing, dish-washing, laundry work and other household uses, it may be roughly estimated that one cubic foot of ordinary illuminating gas will heat one gallon of water to a suitable temperature for domestic uses. The convenience of gas, the lack of dust and ashes are additional considerations which recommend gas for heating water; and with the various appliances now on the market, a suitable heater can be obtained for use under most any known condition of service. Roughly, the gas burning apparatus used for heating water may be divided into three different classes, which are known as instantaneous water heaters, gas water heaters, and automatic instantaneous water heaters. The instantaneous water heaters are the simplest and least expensive of all gas heaters, and, as would be expected, the most restricted in usefulness. Usually, they are used to supply water only to the bath tub or to the bath tub and lavatory in a bath room, leaving the rest of the building piped only for cold water. Nevertheless, this type of water heater has its field of usefulness and gives good service when installed.

Gas water heaters of the other type are attached to the range boiler, where they take the place of a

waterback; and automatic instantaneous water heaters are designed to supply hot water to the entire building, day or night, without any care or attention from the inmates, and with a consumption of gas only when water is being heated.

INSTANTANEOUS WATER HEATERS.

A simple apparatus for heating water instantaneously with gas is shown in Fig. 15. In this illustration part of the casing is removed, so the interior construction may be seen and the operation described. This apparatus will not heat water under pressure, but only when released from pressure and flowing over the plates by gravity. Owing to this fact, the heater must be placed at a higher elevation than the fixture it is intended to supply with hot water. The operation of the heater is as follows: A special gas cock *a* is so constructed that gas cannot be

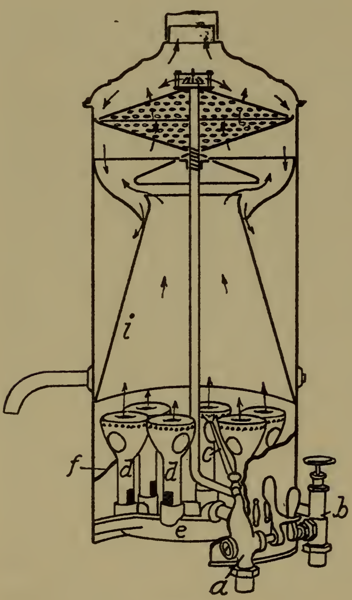

Fig. 15.

turned on to the heater without also turning on the water valve *b,* thus preventing the overheating or burning of the water heating plates. A pilot light *c* is always burning, so that as soon as the gas and water are turned on the gas enters the burners *d d* from the ring *e* to heat the plate surface. When the water is turned on it flows through the valve *b* and up through the standpipe shown in the centre of the cylinder, to near the top of the apparatus, where it is discharged through a spray nozzle and falls in a thin sheet, which spreads out over the entire heating surface *i.* As the water flows over this thin metal surface, it absorbs heat from the flames and hot gases within, so that by the time it reaches the bottom of the compartment and flows out of the spout into the bath tub or other fixture, it is heated ready for use. A drip-ring *f* is provided near the bottom of the cylinder to catch the drip from the beads of moisture which condense on the under side of the heating plates. If this drip ring were not provided, sufficient water would drain onto the floor to keep it damp, rot the woodwork and in other ways become a nuisance.

Instantaneous water heaters are not suitable for heating large quantities of water, nor are they designed to heat any quantity of water to a high temperature; their chief usefulness lies in their adaptability to heat water for bathing purposes, and for this use they are often placed in buildings which

contain bath rooms, but which are not equipped with hot water supply pipes. When used in a bathroom, the heater is placed on a shelf near the fixture to be supplied, so that the heated water will flow direct by gravity into the receptacle. For this purpose they are highly satisfactory and may be depended upon to give entire satisfaction. Another use to which instantaneous water heaters may be put, is to heat the water for bathing and washing at camps and seaside resorts. If gas is not obtainable in the locality, by making a few changes the heater can be converted into a gasoline-burning water heater. When a heater of this type is located in a bathroom, a branch from the discharge tube can be run to the wash basin while the main tube discharges into the bath tub. By placing a valve or cock in the main tube, the water can then be so controlled that it may be discharged at will, either into bath tub or into lavatory. When the valve is open, the water will flow into the bath tub only, and when the valve is closed, the water will flow into the wash basin. To insure there will be no backing up into the basin when the water is wanted at the bath tub, the pipe to the basin should be given a slight upward pitch, so the water will have to rise an inch or more to discharge into the basin. Intelligent care must be exercised in operating a heater when gas is the fuel, for if the cylinder becomes filled with gas, there is liable to be a disastrous explosion when the gas is ignited.

Instantaneous heaters of this description are quite economical in the consumption of gas, but they are limited in usefulness by the fact that they have the capacity to supply only a few fixtures, which must be located close together.

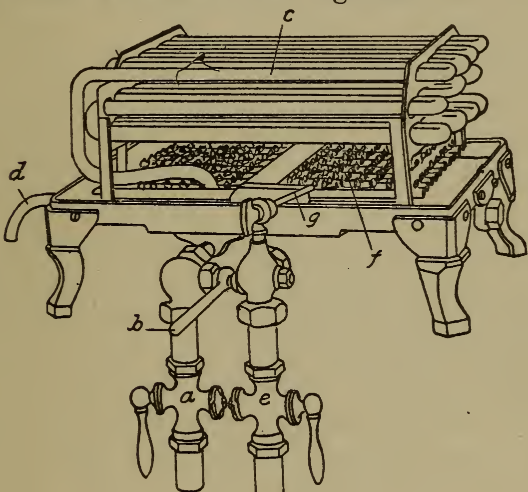

Fig. 16

Another type of instantaneous water heater is shown in Fig. 16. In this heater the water does not come in contact with the products of combustion of the gas, as it does in the type of heater previously shown, consequently the heated water is much purer and can be used for cooking and other purposes, where the heated water will afterward be taken internally. The water in this type of heater has its temperature raised while floating

through a pipe coil, exposed to the flame of gas burners. In the illustration, the casing is shown removed, to expose the interior construction of the apparatus, so the operation can be explained. Cold water enters the coil through the valve *e*, and the flow is regulated by the valve handle *b*, which controls both the gas valve and the water valve, so that gas cannot be turned on and lighted without the water being turned on and the coils filled with water. The coils *c* are so made that the water flows immediately to the top row of pipes, and from there the coil is graded to where the water discharges into the fixture through the discharge tube *d*. By this arrangement of the pipe coil, most of the heat from the burning gas can be absorbed by the water during the brief time required to pass through the heater. The reason for this lies in the fact that the cold water in the top row of pipes is of lower temperature than the hot gases passing over them, and as heat travels from the hotter to the cooler mediums, a transfer of heat takes place from the hot gases to the water within the coils. If, instead of the cold water entering the coils at the top and discharging from the bottom tier, the order were reversed and the cold water entered the coil at the bottom and discharged from the top tier, the hottest water in the coils would be in the pipes at the top, while the coolest gases would likewise be found there. As in that case the temperature

of the water within the top pipes of the coil would be warmer than the gases passing over them, there would be a transfer of heat, but in the inverse order from that desired. Instead of heat passing from the hot gases to the water, the temperature of the water would be lowered by an absorption of heat by the gas.

A supply of gas for the heater is controlled by the gas cock *e*, through which it flows to the burners located beneath the coils. A pilot light *g* serves to ignite the burners when hot water is desired.

It might seem unnecessary to remark that for water heaters, as well as for all other kinds of gas apparatus designed to produce heat, some modification of the Bunsen burner should be used. While there are from 650 to 700 B. T. U. in one cubic foot of illuminating gas, that fact is of no value in heating unless almost all of the possible heat is made available. This is not possible when burning the gas with a yellow flame such as that seen at a gas tip, but the possible heat in the gas can be made available by means of a blue flame, such as that produced by the Bunsen burner, which mixes a certain percentage of air with the gas before combustion or ignition. Instantaneous water heaters of whatever type can be changed to gasoline water heaters, whenever desired. There are many localities, for instance in suburban and country residences, where

illuminating gas is not available; further, there are districts in some small cities where gas mains are not laid in the street, and it is well to bear in mind that if outside the fire limits of the city instantaneous heaters can be changed so they will be available for heating water under such conditions. To do so, the gas burners in the heater must be changed to gasoline burners, as gasoline cannot be burned in an ordinary gas burner. In addition, a tank for storing gasoline must be erected somewhere, preferably outside of the building and a pipe connection made between the heater and the tank. Wherever the tank is located, and whether inside or outside of the building, it must be placed at an elevation above the level of the burners in the heaters, so that the gasoline will flow to the burners by gravity and under slight pressure.

When gasoline is the fuel to be used, the manufacturers will change the burners to suit, if, when ordering the heater, the plumber will but state that he wants the apparatus for burning gasoline.

The combustion of gas produces a greater or less amount of water vapor when the heater is in operation. This vapor condenses on the cool under-side of the plates or pipes when the water is still cool, so that there is usually a slight drip from instantaneous water heaters, even when all the joints, pipes and connections are tight. As this drip is inseparable from all types of instantaneous water

heaters, they should each be set over a drip pan to catch this moisture, and a waste pipe should be provided to carry off this condensation. It will not do to discharge the drip water through the waste pipe into the bath tub or lavatory the heater supplies, as the water would be very liable to stain the fixture. The best way would be to extend the waste pipe from the drip pan to a trapped and water-supplied plain iron sink, which will not be damaged by water stains.

A little practical point which should be remembered by the plumber when connecting up an instantaneous water heater is to connect the water supply pipe to the heater first. By doing so, no damage can result to the heater should the gas be turned on and lighted.

If, on the other hand, the gas were connected to the heater first, and through ignorance or malice some one were to turn on the gas and light it, the plates might be burned, twisted or otherwise damaged by the heat. When the water is connected to the heater first, as it should be, a thin film of water is flowing over the plates before the heat strikes them, and they are thus protected from damage.

In addition to the regular combination gas and water cock which comes with every heater, a separate ground-key stop-cock should be placed both in the gas-supply pipe and the water-supply pipe, so that the heater can be cut out of service at any

time for cleaning or repairs, without necessitating the shutting off of gas from the entire building, at the meter.

GAS SUPPLY TO WATER HEATERS.

An instantaneous gas heater will not give good service if the gas supply is taken from one of the runs in the building, so that when in operation the supply of gas to the heater will fluctuate as lights are turned on or shut off. What is required is an adequate and separate supply of gas conducted through a separate gas service of sufficient size, run from the gas meter direct to the water heater. The size of the meter must also be taken into account. If the meter is intended to supply only the lighting fixtures in the building, it will not be large enough to supply both lights and heater. A 10-light meter is required for the heater alone, and if the supply of gas for the heater is taken from the lighting meter, an extra allowance of the capacity of a 10-light meter should be provided in the house meter. If there is not an adequate supply of gas to the heater at all times, in addition to the decreased heating efficiency of the apparatus, there will likewise be the danger of the light flashing back in the burners and burning with a yellow flame which will produce soot. Indeed, one of the chief troubles experienced with instantaneous water heaters is due to this cause. An accumulation of soot and lamp black forms from the

light in the burners flashing back and burning that way for some time before being discovered. The soot thus deposited forms an insulating covering over the heating surface, which reduces considerably the heat transmitted from the burning gas to the water, consequently a greater quantity of gas must be burned to heat the required amount of water.

With an ample supply of gas furnished under a good pressure, ordinarily a ½-inch gas pipe will provide a suitable supply to an instantaneous water heater, provided the distance from the meter to the heater is not too great. As an average, it may be said that 100 feet would not be too great a distance for that size of pipe. On the other hand, when the supply of gas is scant or the pressure weak the service pipe from the meter to the heater should be at least ¾-inch in diameter. In this case the pipe should be run as direct as possible without unnecessary bends or offsets, and the distance from the meter to the heater should be within 100 feet.

Gas Heaters Must be Vented

The products of combustion of gas are devoid of oxygen, besides containing carbon dioxide and carbon monoxide, which are poisonous. It stands to reason, therefore, that these gases should not be permitted to pour out into the room where the heater is located. If, for instance, the heater were located

in a tightly enclosed bath room, and the gases allowed to pour out into the room while a bather was preparing for the bath, and actually engaged in bathing, instead of the refreshed feeling which ought to follow the ablution, the bather might leave the room feeling weak, dizzy or having a headache, if, indeed, in extreme cases he were not asphyxiated. To avoid any such possibility, the combustion chamber of instantaneous heaters should always be connected with a vent-pipe leading to a flue discharging freely into the atmosphere.

The capacity of instantaneous heaters is much greater than would be expected when their use is considered. The actual capacity of the heaters depends upon the size of the heater and averages from about 90 gallons per hour, which is the capacity of the smallest size, to over 360 gallons per hour for the largest size heaters. The water is not heated to the boiling point, however, but only has the temperature raised high enough for use in bathing and other household pursuits, without tempering with cold water. The capacity of the heater is generally rated as raising the temperature of the stated quantity of water from ordinary temperature, 62° Fahrenheit, to 112° Fahrenheit.

Some means besides a waterback in the coal range is sometimes desirable for heating water in range boilers. When such is the case, the most natural apparatus to select for the purpose is a spe-

cial gas water heater. Of course a heating coil or waterback could be placed in the flame of an ordinary gas range, but so small a percentage of the heat would be utilized that such a method would prove exceedingly expensive as well as unsatisfactory.

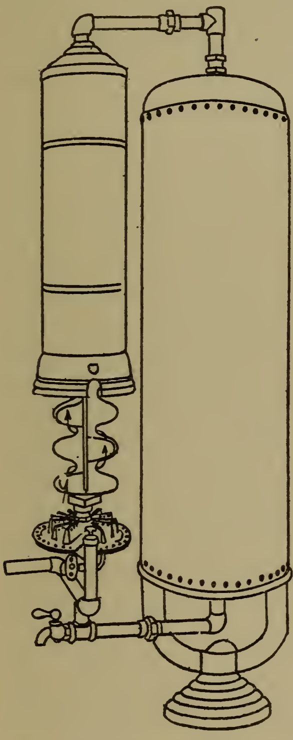

Fig. 17. Gas water heater for range boiler.

To fill just such requirements gas water heaters, similar to that shown in Fig. 17, were designed. Gas heaters of this description are usually formed either with a collection of drop tubes, a spiral coil or a special hollow casting of iron through which the water can flow, and absorb heat from the flame and hot gases applied to the outside of the casting. Whatever may be the interior construction of the water heater, it is provided on the outside with a casing to confine the hot gases in close proximity to the hollow casting, so the water will have the benefit of all the available heat. The heater shown in Fig. 17 is made of cast iron, and in

the illustration the outer casing is shown raised to the top so as to expose the inner casting through which the water flows. This casting is placed directly above a gas burner so the bottom enlargement of the casting will receive the direct heat from the flames while the hot gases pass over and around the other enlargements, as indicated by the arrows. When the casing is down in place the burner is not accessible, consequently a pilot light proves convenient for igniting the gas when the water is to be heated. Naturally, on account of the great amount of gas the heater would consume, it is kept in operation only when hot water is required. A valve in the gas supply to the heater allows the supply to be so regulated that once the water in the tank is heated only enough heat need be supplied to keep the water at that temperature. It might seem needless to add that a Bunsen or atmospheric burner is the only kind suitable for such a heater.

Gas water heaters are placed in the kitchen alongside of the tanks to which they are connected. They could be placed in the basement, cellar or any other part of the house below the level of the boiler, but in that case there would be a greater loss of heat, the exact amount depending on the distance the heater was located away from the hot water tank. The best and most convenient place, therefore, to locate the heating is in the kitchen, as close as possible to the hot water tank. It may then be con-

nected up in any approved way, so there will be a good circulation of water between the heater and the boiler. If desirable, the return pipe from the heater can be connected to the side tapping of the boiler. It is better practice, though, to extend the return pipe to the hot water pipe above the boiler, as shown in the illustration. By this means the hottest water in the entire system can be drawn from the hot water pipes when a faucet is opened. In some installations, instead of a separate connection to the gas water heater, the heater is connected to the return pipe from the coal range to the boiler. This is only done, however, when, in large installations, a large hot water tank out of proportion to the range and the waterback is used, and unless some auxiliary means were provided to help heat the water, instead of the waterback doing so, the cold water in the boiler would chill the waterback and spoil the range for cooking and baking purposes. In whatever way the heater is used, it must be remembered that the cold water pipe must be connected to the bottom of the apparatus, and the hot water pipe to the top of the apparatus, so that as the water is heated in passing through the heater, it can follow the natural tendency to rise.

Further, it is better, when possible, to connect the heater to a hot water boiler, independent of other connections, and independent of the waterback in a coal range.

It is unnecessary to place valves in the connections to a gas water heater, as when there is no fire in the heater there will be little or no circulation through the apparatus. It is not only unnecessary to use valves, but it is absolutely unwise to do so; valves should never be placed in a hot water system when by any possibility they can do harm, and if the valves to a gas water heater were shut off sufficient pressure would be generated within the hollow castings to burst the heater, with perhaps disastrous results.

Gas water heaters are made with sufficient capacities to heat the water in boilers of from 30 to 60 gallons capacity. When larger storage tanks than that are used, if this type of heater is selected, multiple connections with two or more heaters will be required.

The same trouble will be experienced with gas water heaters as is experienced with waterbacks and coal water heaters in limestone regions where the water supplied to the consumers is hard. Incrustations of lime or magnesia will take place inside of the hollow casting through which the water flows until successive deposits completely obstruct the openings, if the lime is not cleaned out before the deposits reach this stage. A gas water heater clogged with lime would prove equally as dangerous as if connected up to the boiler with valved flow and return pipes in which the valves were closed. In

addition to the danger liable to arise from the deposit of lime, the efficiency of the heater is vastly decreased with each successive deposit, so that far more gas will have to be burned to heat a given quantity of water than would be required if the heating surface were clean. The best remedy for preventing clogging of castings or deposits of lime is to follow the instructions previously given in regard to water-backs. It is a good practice to occasionally clean the outside of the water castings also, to remove the deposits of soot and lampblack deposited whenever the flame flashes back at the burner.

In small kitchens which are poorly ventilated gas water heaters should be provided with vent pipes to conduct to the outer air the products of combustion arising from the burning gas. In large, well-ventilated kitchens where a separate vent flue is provided to carry off the odors of cooking, this requirement is not so necessary, although even then it is desirable.

HEATING LARGE BODIES OF WATER.

Wherever gas water heaters are to be used for heating large tanks of water, that is to say, tanks of 100 gallons and over, the multiple type of heater must be used. A compact multiple gas water heater, in which three heaters are used, in connection with one large hot water tank, is shown in Fig. 18. In this illustration, part of the lower part of the hot water tank is broken away to show the location of the heaters, and the manner of connecting them to the boiler. As may be seen, the heaters are set clover-leaf shape, and are snugly nested in cavities formed within the body of the boiler. From these cavities, vent pipes extend to above the top of the tank, so that the products of combustion can escape. If they could not, no hot water could be produced, for the gas would refuse to burn in the absence of air or oxygen. A good feature of the nesting of gas water heaters

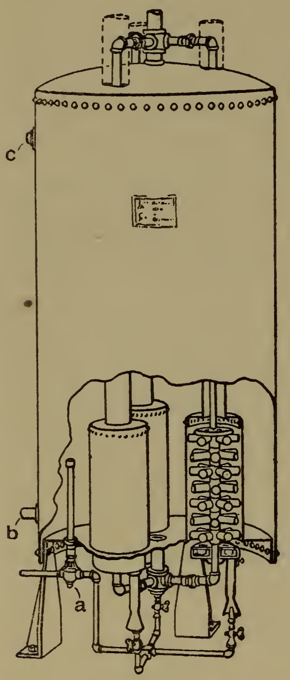

Fig. 18. Compact multiple gas water heater.

within the boiler, as is done in this case, lies in the fact that there is no loss of heat by radiation from the outer surface of the heater casings as there would be if these casings were exposed to the atmosphere. All heat of combustion, even to the exhaust heat in the gases passing up through the vent flues, can be transmitted to the water, so that enclosed heaters of this type develop the maximum efficiency, so far as utilizing all heat contained in the gas is concerned.

It will be noticed that multiple connections consisting of three-way fittings are used to connect the flow pipes from the bottom of the boiler to the bottoms of the heaters, and a like connection is used for connecting the return pipes to the top of the boiler. From the top of the multiple connection on top of the boiler the hot water supply for the building is taken, and from the bottom outlet of the multiple connection at the bottom of the boiler an emptying pipe can be extended to some suitable place of disposal.

To prevent the waste of gas by keeping the heaters going after the water has been raised to the right temperature, a thermostatic arrangement similar to that shown at *a* may be used. This regulator, which automatically controls the supply of gas, is operated by the temperature of the water within the boiler, shutting off the gas when the temperature of the water reaches a pre-determined

point, and turning the gas on again when by use or radiation the temperature of the water has again been lowered beyond that required. Locating the thermostatic tube in the lowest part of the boiler insures a good supply of hot water at all times, for, when the temperature of the water in the lower part of the boiler is cool enough to open the gas cock and thus turn on gas to the heater, to heat the water, there will be a sufficient supply of hot water in the top of the boiler to supply the various fixtures until the heaters catch up with the demand for hot water. The burners used with multiple heaters are of the Bunsen type, and when a thermostat is used, they must be provided with pilot lights or other means for automatically igniting the gas when it is turned on by the thermostat. If there were no means for automatically lighting the gas, and the flues were connected to chimneys leading to the outer air, gas could escape continuously and no evidence of the fact would be noticeable within the building, and no good would be accomplished by the gas.

Side outlets, b and c, are provided in the hot water tank, so that if desired a water back, special coal burning heater or garbage burning water heater can also be connected to the tank.

AUTOMATIC INSTANTANEOUS WATER HEATERS.

In the gas water heaters just considered the heater does the work of a water back, and a hot water

tank is required to store the hot water in. With automatic instantaneous water heaters, on the other hand, no boiler or reservoir is necessary, the heater supplying the hot water as it is wanted and direct to the faucets without the intervention of storage devices of any kind. There are many features about this type of heater which makes it particularly desirable for heating water under many conditions. The heater can be located in the basement or cellar, where the living rooms will not be heated by the radiant heat escaping from the heater casing. Gas is not consumed keeping hot a large volume of water which is constantly giving off heat to the atmosphere, and fuel is being consumed only when hot water is being drawn from a faucet. Having the heater located in the basement or cellar, or in some other compartment away from the living rooms is very desirable in warm climates, whereas in cold parts of the country the additional heat might prove very acceptable in the kitchen. When such is the case an automatic instantaneous water heater may be located in the kitchen, or a gas water heater with storage tank used, both to heat water and keep the kitchen warm.

The greatest use for the automatic instantaneous heaters is found in modern residences, where the effort is made to provide both comfort and convenience in the kitchen. In these buildings gas ranges are substituted for coal ranges, so the kitchen will

be cool in the summer time, and radiators or registers, as the case may be, are provided to heat the kitchen in the winter.

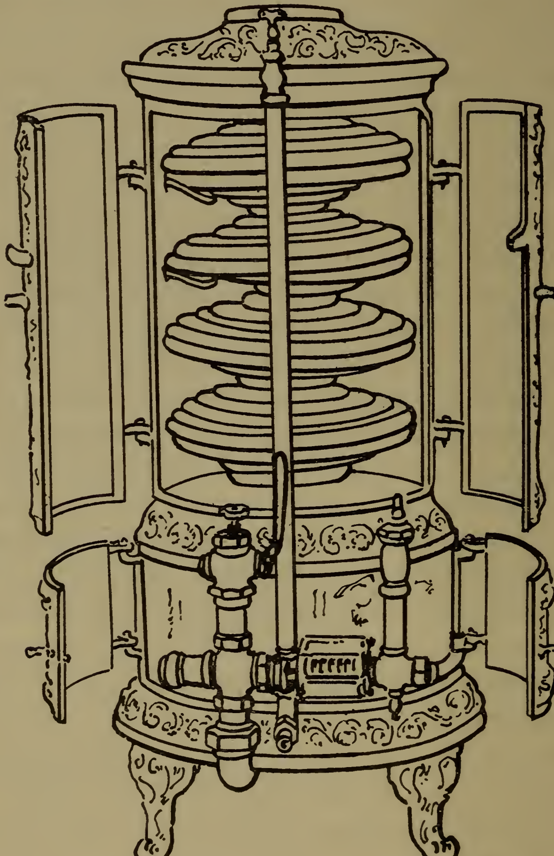

Fig. 19. Sketch showing interior construction of an instantaneous automatic water heater.

An instantaneous automatic water heater is shown in Fig. 19. In this illustration the doors are open

to show the interior construction of the apparatus. The heater consists simply of several coils of copper pipe, occupying the space inside of a casing and placed immediately over a cluster of Bunsen burners. By this construction, most of the heat developed by the combustion of the gas is absorbed by the water coils and transmitted to the water. The heater is also provided with a combination automatic gas and water cock, to control and regulate the flow of gas and water, and a thermostat to shut off the supply of gas, but still leave the water flow, when the temperature of the water flowing through the coils exceeds a certain temperature.

The operation of the heaters is very simple. They are set up in the basement, cellar or any other convenient part of the building and the cold water supply is connected to them in such a way that all water flowing to the hot water faucets in the building will first have to flow through the coils in the heater. After the water pipe in the apparatus is ready for service, all that is necessary then, after the pilot light has been started, is to open a hot water faucet in any part of the building, and hot water will be drawn as long as the faucet is kept open. The important part of heaters of this class is the automatic gas and water cock, which regulates the flow of gas and water respectively through the gas and water service pipes. The apparatus is operated really by the pressure of water in the water pipe. A pilot

light attached to the gas service and located within the heater in close proximity to the cluster of Bunsen burners is always burning; then, as soon as a hot water faucet anywhere in the building is opened, the pressure is correspondingly relieved from the automatic valve. This immediately permits the escape of gas through the water regulated gas valve, which is ignited by the pilot light, and the flames and hot gases heat the water in the coils. This water controlled gas and water valve is unique in that the gas and water are adjusted to each other in such a way that the flow of water through the copper coils is proportioned to the amount of gas which is being consumed, so that just sufficient gas is consumed to heat the water required. That is to say, if the water is flowing through the copper coils in the heater at the rate of three gallons per minute, the consumption of gas is at the rate of three cubic feet per minute, which is just sufficient to heat the three gallons of water from ordinary temperature to about 130° Fahrenheit, which is about the right temperature for domestic water supply. If, on the other hand, water is flowing through the copper coils in the heater at the rate of six gallons per minute the gas will be consumed at the rate of six cubic feet per minute. By this nice adjustment of gas and water to each other there is no waste of gas heating a larger quantity of water than is required, or a smaller quantity of water to a higher temperature than is wanted.

In order to be able to heat the largest quantity of water which they are rated to as fast as the water might flow through the coils there is not only a large amount of heating surface in the coils, but there are likewise a number of burners in the cluster—so many, in fact, that if the gas from these were allowed to burn continuously the water would be heated to far above the desired temperature. To prevent this a thermostat is provided, and the action of the gas burners is intermittent.

The thermostats are provided with an expansive metal rod or some equally sensitive operating device, which is in contact with the water flowing through the coils, and the thermostat is so regulated that when the temperature of the water reaches a certain degree the operation of the thermostat will cut off the supply of gas from all burners but the pilot light. This immediately removes the source of heat, but the water still continues to be warmed by the hot gases remaining in the combustion chamber and the heat stored in the coils, until sufficient cold water has been run through the apparatus to absorb this heat. As soon as it does the lowered temperature of the water causes the gas valve to open; the gas is immediately ignited by the pilot light and the maximum heat is again available in the heater.

Unless ordered otherwise, the thermostat on automatic instantaneous heaters is regulated to shut off the gas when the temperature of the water reaches

140° Fahrenheit. Raising the water to 135 or 140° temperature allows for its being delivered at the fixtures at about 130° temperature, according to the distance the water must travel after leaving the heater and before reaching the faucet. The only loss is that due to radiation and maintaining the temperature of the hot water, but this might amount to a considerable sum if the runs are long and the pipes uncovered and exposed in cold places. To economize on operating expenses the hot water supply pipes from a gas heater of the pressure type should be well protected with an insulating covering to prevent the loss of heat.

As ordinarily constructed, automatic instantaneous heaters are rated to heat from ordinary temperature to 130° Fahrenheit, one gallon of water for each cubic foot of gas consumed; that is, provided the gas tests over 700 British thermal units. Generally, however, the heaters are rated to possess capacities capable of raising one gallon of water 62° Fahrenheit, with the consumption of one cubic foot of gas testing 650 heat units.

Automatic instantaneous water heaters would not prove economical for heating large quantities of water for hotels, apartment houses, asylums, sanitariums, hospitals or other large buildings where the runs of pipe would be long; consequently they are not made with larger capacities than are required for private houses. The heaters are made in

three sizes, the smallest of which has the capacity to raise the temperature of three gallons of water 50° Fahrenheit per minute, with a consumption of three cubic feet of gas, and the largest possesses a capacity of seven gallons of water per minute, raised 50° Fahrenheit, with a consumption of seven cubic feet of gas. The smallest size is intended for buildings having one bathroom, and the largest for buildings having not over four bathrooms.

Automatic instantaneous water heaters would prove objectionable in buildings where large quantities of water must be heated, not only on account of the greater cost of heating water with gas over that of coal when large quantities are to be continuously heated, but for the additional reasons that circulation of hot water could not be economically maintained throughout the building; consequently the hot water pipes would stand full of cold water, which would have to be drawn off and the pipes heated before hot water could be drawn at a faucet, whereas in a properly constructed hot water installation in a hotel or like building hot water should be drawn from the faucet the instant it is opened.

It might be well to add in passing that circulation of hot water throughout the building cannot be economically maintained in large buildings where any type of pressure gas water heater is used.

USE OF STEAM FOR HEATING WATER.

Of all means for heating water there is none so convenient as steam, when a plentiful supply is available for that purpose. So fully is this principle recognized that steam is used for a multitude of purposes when heat must be applied to liquids. One feature of heating water with steam which is valuable in many instances is the fact that by regulating the temperature of the steam any desired degree of heat may be maintained and at a uniform temperature. Advantage is taken of this fact in canning factories, soap manufactories, as well as in hotels and institutions, such as hospitals and asylums, and kettles with steam jackets are used in the preparation of meals and steam coils used for heating water for the various domestic purposes.

The convenience of steam and its entire absence of danger or odors which must be safely conducted out of doors are other factors which make steam a very desirable medium for heating water. Once the steam connection is made there is no attention required other than turning on or shutting off the steam valves, and even this attention may be dispensed with where water must be kept continuously warm, as, for instance, in storage tanks for hot water, by using an automatic temperature regulator

TABLE VII—PROPERTIES OF SATURATED STEAM

Absolute Pressure	Temperature Degrees Fahr.	Heat Units above 32 Degrees Fahr. Contained in 1 Pound of Steam In Water	Latent Heat	Total Heat	Weight of 1 Cubic Foot in Pounds	Volume of 1 Pound in Cubic Feet
14.7	212.0	180.9	965.7	1146.6	.0379	26.37
15	213.1	181.6	965.3	.9	.0387	25.85
16	216.3	184.9	963.0	1147.9	.0411	24.33
17	219.5	188.1	960.8	1148.9	.0435	22.98
18	222.4	191.1	958.7	1149.8	.0459	21.78
19	225.3	193.9	956.7	1150.6	.0483	20.70
20	228.0	196.7	954.8	1151.5	.0507	19.73
21	230.6	199.3	953.0	1152.3	.0531	18.84
22	233.1	201.8	951.2	1153.0	.0554	18.04
23	235.5	204.3	949.5	.8	.0578	17.30
24	237.8	206.6	947.9	1154.5	.0602	16.62
25	240.1	208.9	946.3	1155.2	.0625	16.00
26	242.2	211.1	944.7	.8	.0649	15.42
27	244.3	213.2	943.3	1156.5	.0672	14.88
28	246.4	215.3	941.8	1157.1	.0695	14.38
29	248.4	217.3	940.4	.7	.0719	13.91
30	250.3	219.3	939.0	1158.3	.0742	13.48
31	252.2	221.2	937.7	.9	.0765	13.07
32	254.0	223.0	936.4	1159.4	.0788	12.68
33	255.8	224.8	935.1	.9	.0812	12.32
34	257.5	226.6	933.9	1160.5	.0835	11.98
35	259.2	228.3	932.7	1161.0	.0858	11.66
36	260.9	230.0	931.5	.5	.0881	11.36
37	262.5	231.6	930.4	1162.0	.0904	11.07
38	264.1	233.3	929.2	.5	.0927	10.79
39	265.6	234.8	928.1	.9	.0949	10.53
40	267.2	236.4	927.0	1163.4	.0972	10.28
41	268.7	237.9	926.0	.9	.0995	10.05
42	270.1	239.4	924.9	1164.3	.1018	9.83
43	271.6	240.8	923.9	.7	.1041	9.61
44	273.0	242.3	922.9	1165.2	.1063	9.40
45	274.3	243.7	921.9	.6	.1086	9.21
46	275.7	245.1	920.9	1166.0	.1109	9.02
47	277.0	246.4	920.0	.4	.1131	8.84
48	278.3	247.7	919.1	.8	.1154	8.67
49	279.6	249.1	918.1	1167.2	.1177	8.50
50	280.9	250.3	917.3	.6	.1199	8.34
51	282.2	251.6	916.4	1168.0	.1222	8.19
52	283.4	252.9	915.5	.4	.1244	8.04
53	284.6	254.1	914.6	.7	.1267	7.89
54	285.8	255.3	913.8	1169.1	.1289	7.76
55	287.0	256.5	912.9	.4	.1312	7.62
56	288.1	257.7	912.1	1169.8	.1334	7.50
57	289.3	258.9	911.3	1170.2	.1357	7.37
58	290.4	260.0	910.5	.5	.1379	7.25
59	291.5	261.1	909.7	.8	.1401	7.14

TABLE VII—CONTINUED.

Absolute Pressure	Temperature Degrees Fahr.	Heat Units above 32 Degrees Fahr. Contained in 1 Pound of Steam In Water	Latent Heat	Total Heat	Weight of 1 Cubic Foot in Pounds	Volume of 1 Pound in Cubic Feet
60	292.6	262.3	908.9	1171.2	.1424	7.02
61	293.7	263.3	908.2	.5	.1446	6.92
62	294.7	264.4	907.4	.8	.1468	6.81
63	295.8	265.5	906.6	1172.1	.1491	6.71
64	296.8	266.6	905.9	.5	.1513	6.61
65	297.8	267.6	905.2	.8	.1535	6.52
66	298.8	268.7	904.4	1173.1	.1557	6.42
67	299.8	269.7	903.7	.4	.1579	6.33
68	300.8	270.7	903.0	.7	.1602	6.24
69	301.8	271.7	902.3	1174.0	.1624	6.16
70	302.8	272.7	901.6	.3	.1646	6.08
71	303.7	273.6	901.0	.6	.1668	6.00
72	304.7	274.6	900.3	.9	.1690	5.92
73	305.6	275.6	899.6	1175.2	.1712	5.84
74	306.5	276.5	898.9	.4	.1734	5.77
75	307.4	277.4	898.3	.7	.1756	5.69
76	308.3	278.4	897.6	1176.0	.1778	5.62
77	309.2	279.3	897.0	.3	.1800	5.56
78	310.1	280.2	896.3	.5	.1822	5.49
79	311.0	281.1	895.7	.8	.1844	5.42
80	311.9	282.0	895.1	1177.1	.1866	5.36
81	312.7	282.8	894.5	.3	.1888	5.30
82	313.6	283.7	893.9	.6	.1910	5.24
83	314.4	284.5	893.3	.8	.1932	5.18
84	315.3	285.4	892.7	1178.1	.1954	5.12
85	316.1	286.2	892.1	.3	.1976	5.06
86	316.9	287.1	891.5	.6	.1998	5.01
87	317.7	287.9	890.9	.8	.2020	4.95
88	318.5	288.8	890.3	1179.1	.2042	4.90
89	319.3	289.6	889.7	.3	.2063	4.85
90	320.1	290.4	889.2	.6	.2085	4.80
91	320.9	291.2	888.6	.8	.2107	4.75
92	321.7	291.9	888.1	1180.0	.2129	4.70
93	322.4	292.8	887.5	.3	.2151	4.65
94	323.2	293.5	887.0	.5	.2173	4.60
95	323.9	294.3	886.4	.7	.2194	4.56
96	324.7	295.1	885.9	1181.0	.2216	4.51
97	325.4	295.8	885.4	.2	.2238	4.47
98	326.2	296.6	884.8	.4	.2260	4.43
99	326.9	297.3	884.3	.6	.2281	4.38
100	327.6	298.1	883.8	.9	.2303	4.34
101	328.3	298.8	883.3	1182.1	.2325	4.30
102	329.1	296.6	882.7	.3	.2346	4.26
103	329.8	300.3	882.2	.5	.2368	4.22
104	330.5	301.0	881.7	.7	.2390	4.19
105	331.2	301.7	881.2	.9	.2411	4.15
106	331.9	302.4	880.7	1183.1	.2433	4.11
107	332.6	303.2	880.2	.4	.2455	4.07

TABLE VII—CONTINUED.

Absolute Pressure	Temperature Degrees Fahr.	Heat Units above 32 Degrees Fahr. Contained in 1 Pound of Steam			Weight of 1 Cubic Foot in Pounds	Volume of 1 Pound in Cubic Feet
		In Water	Latent Heat	Total Heat		
108	333.2	303.9	879.7	1183.6	.2476	4.04
109	333.9	304.6	879.2	.8	.2498	4.00
110	334.6	305.3	878.7	1184.0	.2519	3.97
111	335.3	305.9	878.3	.2	.2541	3.94
112	335.9	306.6	877.8	1184.4	.2563	3.90
113	336.6	307.3	877.3	.6	.2584	3.87
114	337.2	308.0	876.8	.8	.2606	3.84
115	337.9	308.6	876.4	1185.0	.2627	3.81
116	338.5	309.3	875.9	.2	.2649	3.78
117	339.2	310.0	875.4	.4	.2670	3.75
118	339.8	310.6	875.0	.6	.2692	3.72
119	340.4	311.3	874.5	.8	.2713	3.69
120	341.1	311.9	874.1	1186.0	.2735	3.66
121	341.7	312.5	873.6	.1	.2757	3.63
122	342.3	313.1	873.2	.3	.2778	3.60
123	342.9	313.8	872.7	.5	.2799	3.57
124	343.5	314.4	872.3	.7	.2821	3.55
125	344.1	315.1	871.8	.9	.2842	3.52
126	344.7	315.7	871.4	1187.1	.2864	3.49
127	345.3	316.3	871.0	.3	.2885	3.47
128	345.9	316.9	870.5	.4	.2907	3.44
129	346.5	317.5	870.1	.6	.2928	3.42
130	347.1	318.1	869.7	.8	.2950	3.39
131	347.7	318.7	869.3	1188.0	.2971	3.37
132	348.3	319.3	868.9	.2	.2992	3.34
133	348.9	319.9	868.4	.3	.3014	3.32
134	349.4	320.5	868.0	.5	.3035	3.30
135	350.0	321.1	867.6	.7	.3057	3.27
136	350.6	321.7	867.2	.9	.3078	3.25
137	351.1	322.3	866.8	1189.1	.3099	3.23
138	351.7	322.8	866.4	.2	.3121	3.20
139	352.3	323.4	866.0	.4	.3142	3.18
140	352.8	324.0	865.6	.6	.3163	3.16
141	353.4	324.6	865.1	.7	.3185	3.14
142	353.9	325.1	864.8	.9	.3206	3.12
143	354.5	325.7	864.4	1190.1	.3227	3.10
144	355.0	326.2	864.0	.2	.3249	3.08
145	355.6	326.8	863.6	.4	.3270	3.06
146	356.1	327.4	863.2	.6	.3291	3.04
147	356.6	327.9	862.8	.7	.3313	3.02
148	357.2	328.5	862.4	.9	.3334	3.00
149	357.7	329.0	862.0	1191.0	.3355	3.98
150	358.2	329.6	861.6	.2	.3376	2.96
160	363.3	334.9	857.9	1192.8	.3589	2.79
170	368.2	339.9	854.4	1194.3	.3801	2.63
180	372.9	344.7	851.0	1195.7	.4012	2.49
190	377.4	349.3	847.7	1197.0	.4223	2.37
200	381.6	353.7	844.6	1198.3	.4433	2.26

to cut off the steam when the water reaches a certain temperature.

In large institutions steam under pressure of at least 80 pounds per square inch is available, and in factories even higher pressures than 80 pounds are maintained. But assuming that a pressure of 80 pounds gauge pressure is all that is available, with such a pressure the temperature of the steam would be 323 degrees Fahrenheit, so that water could be quickly boiled by means of steam at such a high temperature. If, on the other hand, steam with a temperature no higher than that of boiling water is desired, there is usually enough exhaust steam available around an institution to use for this purpose. If not, by means of a pressure reducer, the pressure can be brought down to correspond with the temperature desired. When the pressure of the available steam is known the corresponding temperature can be found in Table VII. In this table may also be found the heat units above 32 degrees Fahrenheit contained in one pound of steam at the various temperatures, the weight in pounds of one cubic foot of steam at the various pressures and the volume or space in cubic feet occupied by one pound of steam at the various pressures. For instance, it will be found that a pound of steam at an absolute pressure of 14.7 pounds, which occupies

26.37 cubic feet at 111 pounds pressure absolute, occupies only 3.94 cubic feet of space.

There is a great deal of valuable information in this table, with which the plumber should make himself familiar, as a thorough understanding of the various data contained will make simple many problems of hot-water heating. In applying the table it must be remembered that the pressures are given as absolute pressures. To convert them into gauge pressures 14.7 pounds must be subtracted from each absolute pressure reading. For instance, the first item in the table is 14.7 pounds absolute pressure. That means that while steam is forming in a boiler no pressure would be indicated on the pressure gauge, and that the temperature of the steam and water in contact would be 212 degrees Fahrenheit.

STEAM CONNECTIONS TO RANGE BOILERS.

Steam is sometimes available, so it can be used for heating the water in range boilers for domestic use. At other times the steam is available only during the cold months of the year, and during the rest of the time the water must be heated in a waterback, coil or gas heater. When the water in a range boiler is to be heated with steam a special steam coil must be placed in the boiler, and this must be done before the bottom end is riveted into the boiler. A kitchen range boiler fitted with a

steam coil is shown in perspective in Fig. 20. In this illustration part of the lower portion of the plate is broken away to show the location and construction of the steam coil. The coil is simply a spiral of pipe, which is fitted snugly inside of the boiler and has the two ends projecting through the side of the boiler plate, so they can be connected to the steam and return pipes. It will be noticed that the coil grades downward from where it enters the top opening to the boiler to where the other end is again returned to the outside of the tank. The reason for this is so that water from the steam which is condensed in the coil can flow naturally by gravity to the natural outlet. If the coil were trapped at any point water of condensation would be retained in the and cause a rattling, snapping sound within the boiler, besides interfering with the free circulation of steam through the coil.

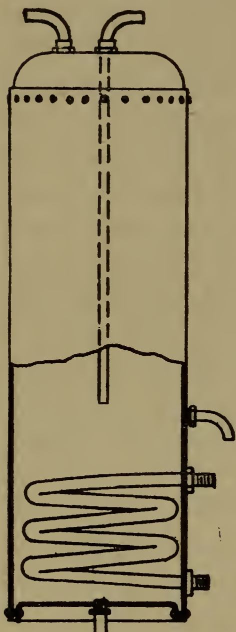

Fig. 20. Range boiler fitted with steam coil.

It will further be observed that the steam coil is located at the bottom of the range boiler. If it

were not located at the bottom the capacity of the boiler would be cut down in direct proportion to the distance of the coil from the bottom. It will be remembered that at all ordinary temperatures water expands and becomes lighter upon being heated. That being true, if the coil be located at the bottom of the tank when the steam is turned on the water which is in contact with the coil will become hot, expand and rise to the top of the boiler, while its place is occupied by a cold current of water flowing down along the sides of the boiler, thus setting up a local circulation throughout the entire contents of the tank. If, now, instead of locating the coil at the bottom of the tank it were placed near the top, the water in contact with the coil would become hot, expand and rise to the top of the tank, as in the first instance, but the local circulation set up would not go any deeper than the bottom of the coil, while the water below that level might be actually cold when the water at the top of the boiler was boiling. It will thus be seen that the location of the steam coil in a range boiler has a marked influence on the capacity of the boiler.

The steam supply to the heating coil in a boiler should be connected to the upper inlet to the coil and the return pipe should be connected to the lower inlet to the coil. Valves should be placed both on the steam pipe and the return pipe, so steam can be cut off from the boiler at any time. A steam coil

in a range boiler does not interfere with the ordinary outlets to the boiler, which are left in condition to be connected up to a range waterback or gas heater. When ordering a range boiler with a steam coil it is well, however, to state just where the steam and return connections shall project through the shell. It is better practice still to send a sketch showing size and location of the outlets to the coil. Almost any kind of tubing used in plumbing work may be made up into a steam coil for range boilers, but on account of the greater capacity to transmit heat possessed by copper over other metals copper coils are generally used for this purpose. The copper pipe is seamless drawn tubing of iron pipe size, and is fully as strong as wrought pipe.

HEATING WATER WITH LIVE STEAM.

Live steam is used for heating water principally in hotels and large institutions where steam is required for power throughout the entire year. It is utilized by passing the steam through steam coils, submerged in the water to be heated. Large special storage tanks are provided for the storage of the hot water, and the steam coils are placed inside of these tanks. When vertical tanks are used a spiral coil, similar to the one used in range boilers, is placed in the tanks. However, in most buildings horizontal tanks are used, as they can easily be suspended from the ceiling beams, thus leaving the

floor space beneath free for other uses. When horizontal tanks are used a different type of coil is generally used, although a spiral coil would be available for the purpose.

A horizontal tank, fitted with a steam coil for the circulation of live steam, is shown in Fig. 21. In this form of construction the coil occupied a vertical position in the centre of the tank, with the lowest pipe of the coil close to the bottom of the tank. The coil which is made up with return bends, is held in place by means of two supports, designed to stay the pipes and keep them from getting out of place. The live steam pipe is connected to the pipe of the coil at *a* and circulates through the entire length of the combined pipes, parting

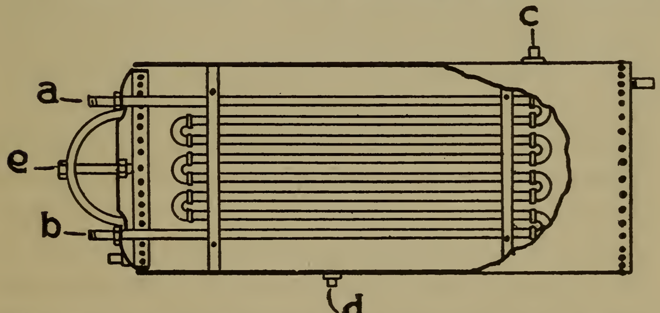

Fig. 21. A horizontal tank fitted with coil for live steam.

with its heat as it passes along, until, condensed to water, it finally passes out through the bottom pipe of the coil into the return connection which is attached at *b*. The value of having a coil of this de-

scription in a tank, instead of grouping all of the pipes together near the bottom, lies in the fact that the condensed steam can be cooled to a lower temperature, or in other words will impart more of its heat to the water. The coldest part of the water is in the lowest part of the tank, and so long as the water there is not hotter than the water of condensation within the coil, it will absorb more heat from the condensed steam until the temperature of the water within the coil, and that in the tank outside, are about at the same degrees.

The hot water connection to this tank is taken off at *c*, from the top of the tank where the hottest water is stored, and the cold water pipe is connected to the tank at *d*. The cold water pipe could be connected to the top of the tank the same as for the cold water connection to a range boiler, but in that case a tube would have to be continued down to near the bottom of the tank. If a circulation pipe is used in the building where water is heated with live steam in a coil, as shown in the illustration, the return or circulating pipe should be connected to the bottom side of the tank, or to one of the ends but very low down. In order that the coil may be placed in a hot water tank and so that the coil will afterwards be accessible for alterations and repairs a manhole should be provided in one of the ends, to the tank. At *e* in the illustration is shown the yoke which holds the manhole cover

for this tank in place. It will be noticed that the opening is large enough to permit a man to enter the tank.

HEATING WATER WITH EXHAUST STEAM.

When steam has done useful work, expansively, by being expanded in the cylinder of an engine or pump, it still is capable of doing useful work by parting with the heat it still contains. To utilize this heat, which would otherwise be wasted, special coils are made for horizontal tanks, so that water can be heated with exhaust steam. It is desirable in heating with exhaust steam that as little back pressure as possible be put on the cylinders from which the steam is taken, otherwise the reduced power of the engines would more than offset the saving effected by using the exhaust steam for heating purpose. In order that but little resistance will be offered when steam flows through the coils of an exhaust steam hot water tank, the pipes are made larger than when live steam is used, bends are made instead of using elbows and return bends, and special headers or manifold fittings are used so the steam and water of condensation will not have to travel continuously through the entire coil. With these provisions observed, exhaust steam proves, within limited temperatures, as good a medium as live steam for heating water, and possesses the additional advantage in its favor that the cost of the steam is practically nothing, as, if

it were not used for that purpose, the heat and vapor would be wasted. Exhaust steam on the other hand, is open to the objection that it cannot heat water to a greater temperature than 212 degrees Fahrenheit, while live steam under pressure on the contrary can heat water as high as 300 degrees Fahrenheit.

A hot water tank fitted with a coil for the use of exhaust steam, is shown in section in Fig. 22.

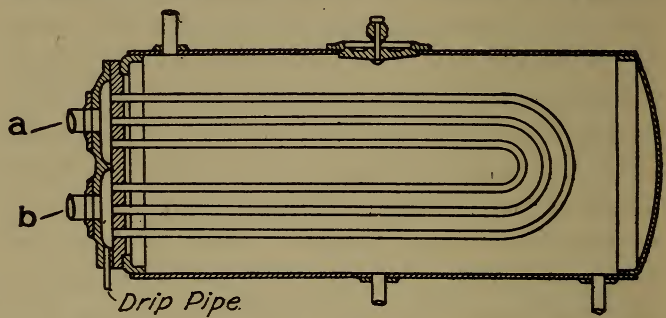

Fig. 22. A hot water tank fitted with a coil for exhaust steam.

This tank may be used either as a hot water storage tank to supply hot water to a building or as a tank for cooling exhaust steam where it must be discharged into the sewer, or in some other place where the puffing of steam would be objectionable. The hot and cold water connections to the tank, likewise the circulation connections, should be made in the same manner as if the tank were heated with live steam flowing through the coils, for the water supply part of both tanks are identical and they

differ only in the construction of the steam coils. All the principal features of an exhaust steam heating coil are shown plainly in the illustration. The inlet or exhaust pipe from the pump or engine is connected to the coil at *a*; from the enlarged chamber within the head casting, the exhaust steam can pass through any one of the three pipes shown, to the outlet chamber on the lower side of the tank, to which is connected the outlet pipe *b*. It will be noticed that the coils are made up without fittings, long sweeping pipe bends taking the place of return bends in ordinary coil construction.

It might be well to point out that while exhaust steam cannot well be used in a coil made for high-pressure live steam, live steam can safely be used in coils made for exhaust steam pressure. It should likewise be remembered that as the coil placed in a hot water tank for heating the water with exhaust steam is designed to heat the water with steam at 212 degrees Fahrenheit, when high pressure steam of 300 or more degrees Fahrenheit is used, the water will be made much hotter than is desirable. This, of course can be prevented by reducing the live steam, to about atmospheric pressure before discharging it into the exhaust steam coil. It is good practice when fitting up a hot water tank to be heated with exhaust steam to also make a connection of live steam to the coil so that live steam can be turned on to keep the water

warm if it ever becomes necessary to shut down the pump or engine for repairs.

Steam coils for hot water tanks may be made of any suitable materials. Generally, however, they are made of copper, brass or wrought pipe. Copper and brass pipes will last longer than wrought pipes, which are liable to corrode through in a very short time and furthermore, they will transmit more heat to the water per square foot of heating surface or lineal foot of pipe. For these reasons, either copper pipe or brass pipe is preferable to iron pipe for steam coils in tanks.

The amount of heating surface required in a steam coil for heating water in a tank is a matter of importance to the plumber or fitter who installs the plant. Roughly, it may be said that the proportion of heating surface to the capacity of the tank should be about 1 to 10. That is to say, for every 10 gallons capacity of the tank, there should be one foot of heating surface in the coil. If the heating coil be made up of 1 inch pipe, the size of the coil can be proportioned, by allowing 3½ lineal feet of the pipe for every 10 gallons of water to be heated.

HEATING WATER WITH STEAM IN CONTACT.

One of the simplest and best methods for heating water with live steam, is to bring the steam into direct contact with the water to be heated, instead of causing it to circulate through pipe coils,

submerged in the water. The reason that this is a good method lies in the fact that it is the quickest, the steam parting with its heat to the water almost instantaneously, and the method is economical as it requires no submerged coils or other expensive apparatus. Owing to some disadvantages of this method of heating water it is not used in domestic practice but finds its greatest field of usefulness in industrial plants heating large vats of water. It likewise is extensively used to heat water in swimming pools, and for heating water for dish washing in hotels, restaurants and large institutions where many dishes are soiled every day.

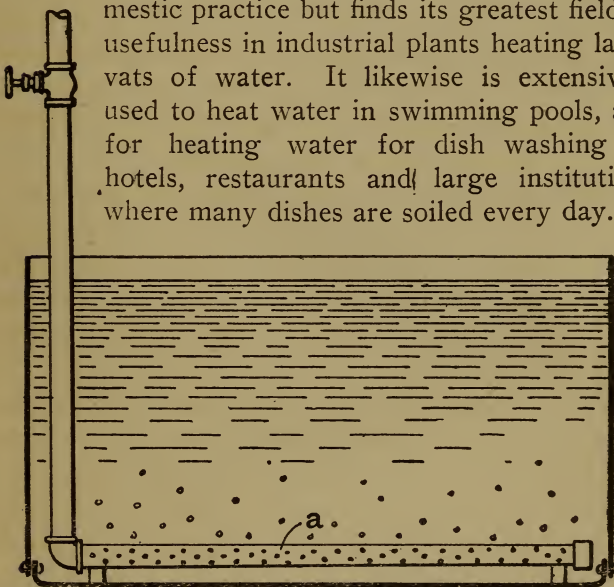

Fig. 23. Shows how steam can be piped into a tank of water.

The usual method of bringing the steam into contact with the water is to force it through a perforated pipe, located near the bottom of the tank, and covered with water. The manner of

piping the steam into the tank of water is shown in Fig. 23. A capped and perforated pipe *a,* is illustrated submerged in a tank of liquid. The perforated pipe which is raised slightly above the bottom of the tank, to permit the escape of steam from all sides, is connected to the vertical line of pipe which is valved to control the supply of steam and permit it to be turned off or on at will, by the attendant. If the tank is a large one, instead of a single perforated pipe, a number of them may be connected to a manifold header supplied with steam from a large pipe having a capacity of the three smaller ones.

In order that the steam may escape freely and with the pressure sufficiently reduced so it will not be carried direct to the surface of the water in the tank, the escape pipes should be liberally supplied with perforations. To insure the best results the combined area of the perforations should be equal to 8 times the area of the perforated pipe to equal it in capacity. Ordinarily the individual perforations need not be very large. In brass or copper pipe, or in any other medium which is not liable to become obstructed by a formation of rust or other deposits the perforations need not be over ⅛-inch in diameter. In very large vats, however, heated with steam discharged through very large pipes, the perforations may be from ¼-inch to ⅜-inch in diameter.

Copper and brass are suitable materials for perforated pipes, when used for heating pure water, or liquors which contain no acids injurious to those materials. When, however liquids containing acids are to be heated, a metal, alloy, or other substance which will withstand the action of the acid must be selected. Tubing made of Tobin Bronze will resist the action of most acids used in manufacturing processes and this material should be kept in mind by plumbers, not only for use in connection with steam water heaters, but for any other purpose found useful for in the calling.

It must be borne in mind that only good, pure, live steam is suitable for heating water by direct contact. Steam which has been used expansively in engines, pumps or other apparatus is not suitable for the purpose. The reason for this lies in the fact that cylinder oils and other lubricants used around machinery come in contact with the steam passing through the cylinders and if the steam becomes saturated or charged with oil, as it very likely will, the oil would form on the surface of water in the tank, and attach itself to anything which was put in or taken out of the water. Besides, for many industrial purposes, the taste of oil in the water used would spoil the article. For instance, if string beans or peas were being boiled in open vessels by means of steam in direct contact with the water, the oil in the steam would

flavor the vegetables and render them unfit for canning. If on the other hand it were clothes that were being boiled, a deposit of oil on the fabrics might do great injury to them. For these reasons when heating water with steam in direct contact, only pure live steam should be employed.

A serious drawback to the use of steam for heating water by direct contact is due to the fact that when the steam is brought into contact with water in an open vessel it causes a loud rattling hammering noise, which drowns the sound of everything else nearby. This is caused by the steam bubbles which when they escape from the perforations start toward the surface, where, if they reach it, they collapse with a report. If, however, the water is very cold, the bubbles of steam are condensed or collapsed almost as soon as they come in contact with the water and the water rushing in to fill the vacuum caused by the collapse of the bubble, causes a report like the muffled discharge of a gun. For this reason, water is heated with steam in direct contact through perforated pipes, only when noise is not objectionable.

If a slight noise is not objectionable and the method adopted to overcome it is not objectionable for other reasons, water may still be heated by steam in direct contact, discharged through a perforated pipe. If, after the perforated pipe is set in place, the bottom of the tank to above the level of

the pipe be covered with clean pebbles about the size of peas, there will be a noise when the steam is turned on, but it will not be so loud or annoying as when the pebbles are not used. The reasons for this are twofold. In the first place, the presence of the pebbles breaks up the steam bubbles into smaller sizes so that when they do collapse the collapsing bubbles are small and consequently have a mild report. In the second place the water cannot rush together so readily to fill the vacuum caused by the collapsing bubble and the more gradually the water comes together, the lighter will be the report.

When calculating the amount of steam which will be required to heat water by direct contact, a simple rule which will be found approximately correct, is to allow 1 pound of steam for each gallon of water to be heated. This is assuming that the water is no colder than 60 degrees Fahrenheit, and that the temperature need not be raised more than 180 degrees or 190 degrees Fahrenheit. If water must be heated to the boiling point an allowance of perhaps 1½ pounds of steam for each gallon of water will be found more nearly correct. A feature of heating water with steam in direct contact, which must not be overlooked, is the fact that the volume of water in the tank is thereby increased. This would naturally follow on account of the steam being discharged into the water. The al-

lowance which must be made for this increase can be easily calculated when the quantity of water to be heated is known and the tank can be proportioned accordingly. When one pound of steam is condensed to water, the water, of course, will weigh as much as the steam did. That being true, for each pound of steam added to the water, the water would be increased in weight one pound, and as one pound of steam will be added to the tank for each gallon of water heated, all that will be necessary to find the total amount will be to divide the quantity of water to be heated by 8.33 which is the weight of one gallon of water and the quotient will be the number of gallons of water condensed from the steam which will be added to the water in the tank.

Heating Water With Steam Nozzles.

A nozzle for heating water, noiselessly, by means of steam in direct contact, is shown in perspective in Fig. 24. It consists simply of an outward and upward discharging steam nozzle, covered with a shield which has numerous openings for the admission of water so that the jet takes the form of an inverted cone, discharging upwards. To make the operation of the apparatus noiseless, air is admitted through a small pipe and drawn in by the jet. By mixing with the steam this air prevents the sudden collapse of bubbles, and the consequent

noise which is such a great objection to heating by direct steam in the old way. A valve or stop cock should be placed on the air pipe so the supply of air can be regulated to the quantity most desirable.

When water is to be heated to a less temperature than 165 degrees Fahrenheit and that temperature is sufficient for all domestic purposes, the

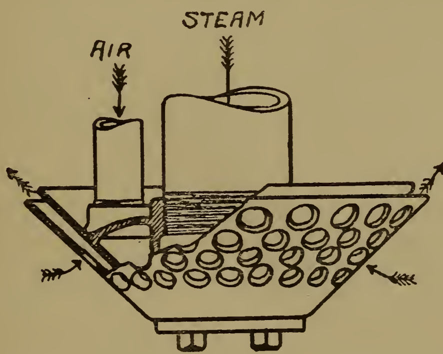

Fig. 24. Shows a nozzle for heating water noiselessly by means of steam in direct contact with the water.

air pipe need not be used, as the heater will operate noiselessly without it. If however, the temperature of the water must be raised above 165 degrees Fahrenheit, the air pipe should be used. When the pressure of steam is sufficient, air need not be delivered to the nozzle under pressure. When however, the steam pressure is low the air must also be delivered under pressure to insure the noiseless operation of the apparatus.

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